AIRS Land Surface Temperature and Emissivity Validation

Bob Knuteson
Hank Revercomb, Dave Tobin, Ken Vinson, Chia Lee

University of Wisconsin-Madison
Space Science and Engineering Center
Robert.Knuteson@ssec.wisc.edu

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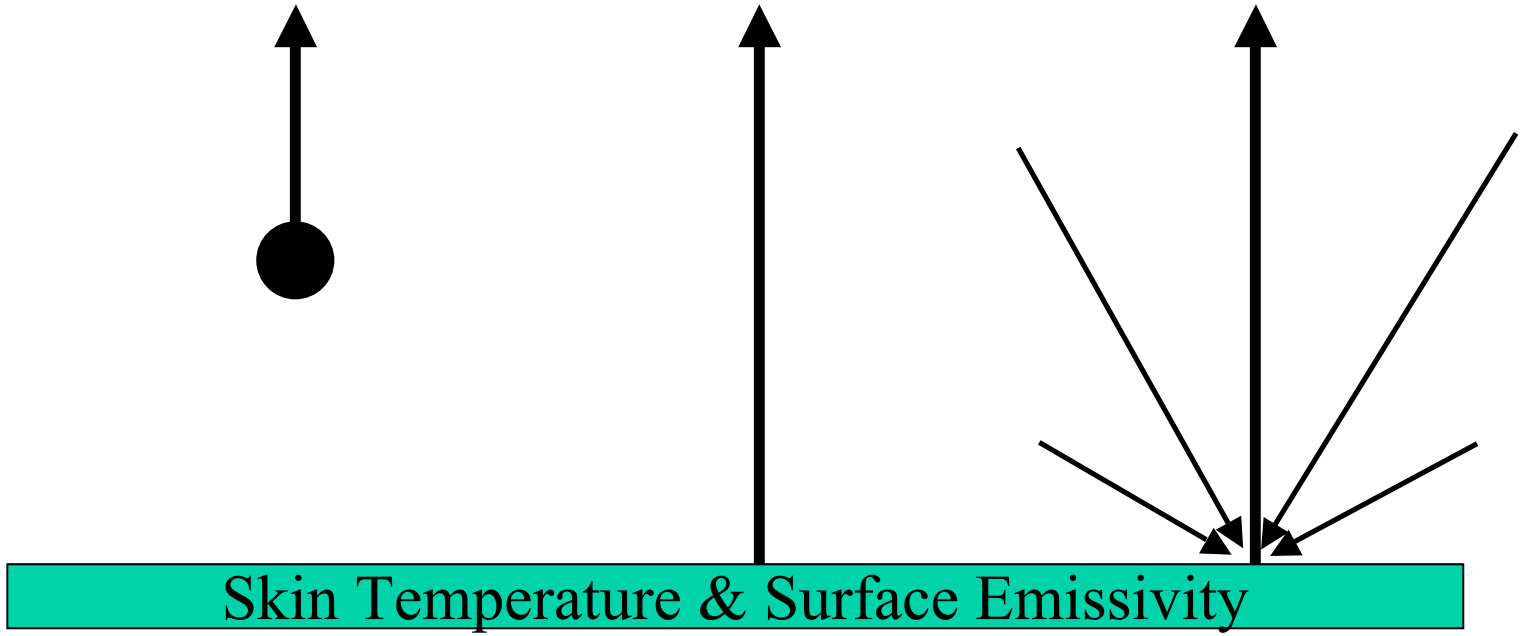
Topics

- IR Emissivity for Clear AIRS FOVs
  (Algorithm provided to JPL and JCDA.)

- AIRS Temperature Validation
  (AIRS/MODIS Level 3 comparison.)

Infrared Radiative Transfer Equation (lambertian surface)

$$N_\nu^{\uparrow} = \underbrace{\int B_\nu(T(P))d\tau_\nu}_{N_\nu^{atm\uparrow}} + \underbrace{\tau_\nu^{tot} \cdot e_\nu \cdot B_\nu(T_S)}_{\text{Surface Emission}} + \underbrace{\tau_\nu^{tot} \cdot (1 - e_\nu) \cdot \overline{N_\nu}^{\downarrow}}_{\text{Surface Reflection}}$$



$$N_\nu^{\uparrow} = \int B_\nu(T(P))d\tau_\nu + \tau_\nu^{tot} \cdot e_\nu \cdot B_\nu(T_S) + \tau_\nu^{tot} \cdot (1 - e_\nu) \cdot \overline{N}_\nu^{\downarrow}$$

Approximate Solutions:

$$e_\nu = N_\nu^{\uparrow} / B_\nu(T_S)$$

(spectral relative)

$$e_\nu = (N_\nu^{\uparrow} - \int B_\nu(T(P))d\tau_\nu) / (\tau_\nu^{tot} \cdot B_\nu(T_S))$$

(atmospheric corrected spectral relative)

$$e_\nu = [(N_\nu^{\uparrow} - \int B_\nu(T(P))d\tau_\nu) - \tau_\nu^{tot} \cdot \overline{N}_\nu^{\downarrow}] / [\tau_\nu^{tot} B_\nu(T_S) - \tau_\nu^{tot} \cdot \overline{N}_\nu^{\downarrow}]$$

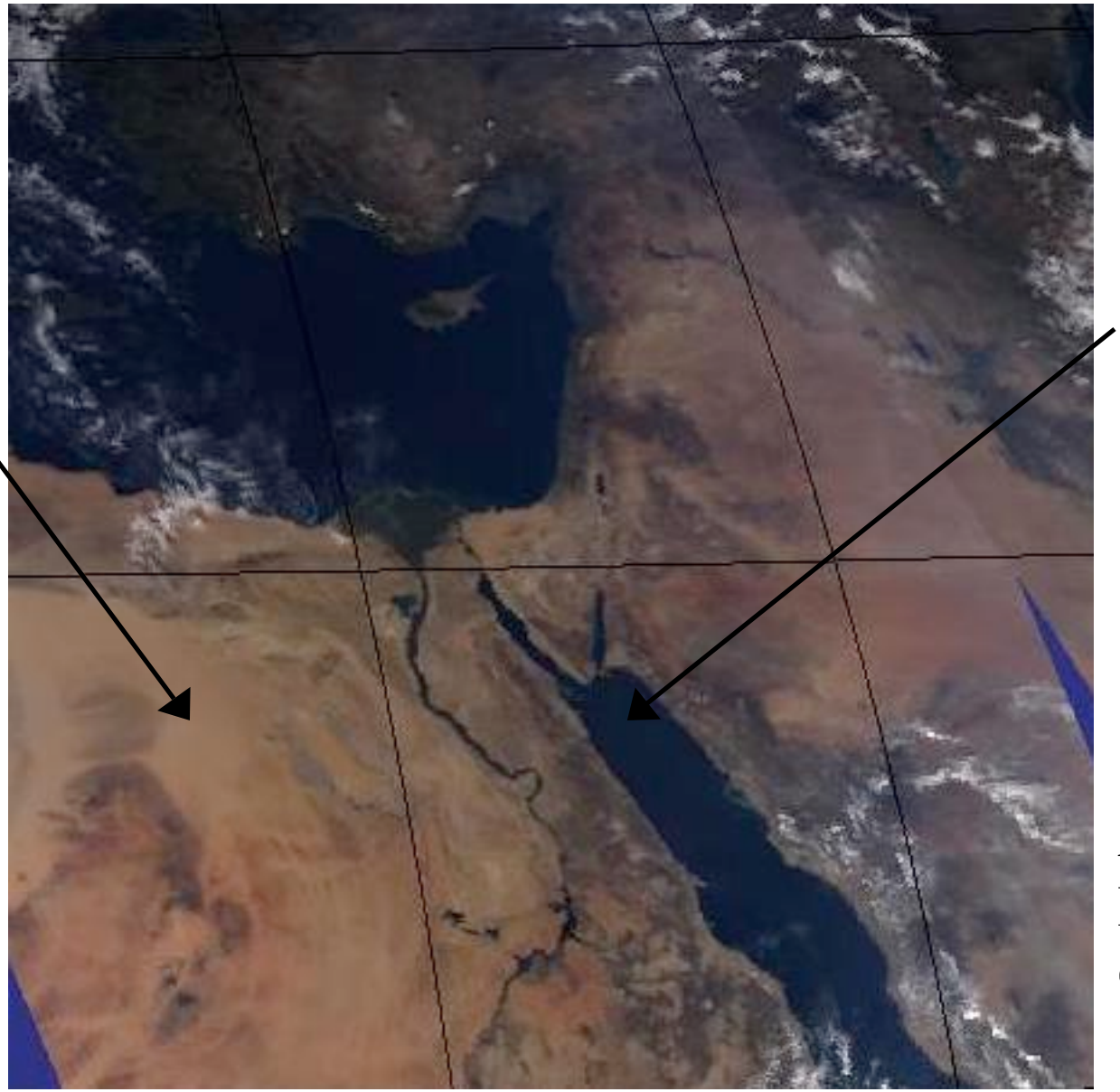
(formal solution - known atmosphere
- unknown skin temperature)

AIRS Relative Emissivity and Temperature

16 November 2002

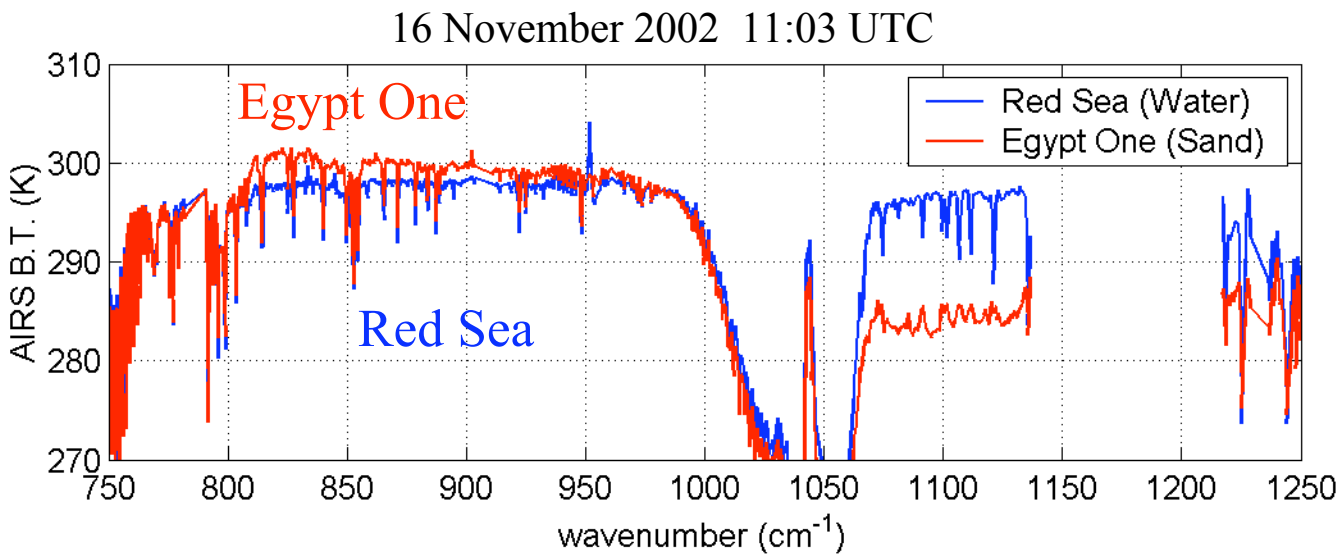
Focus Day

MODIS Image of Egypt & Nile River



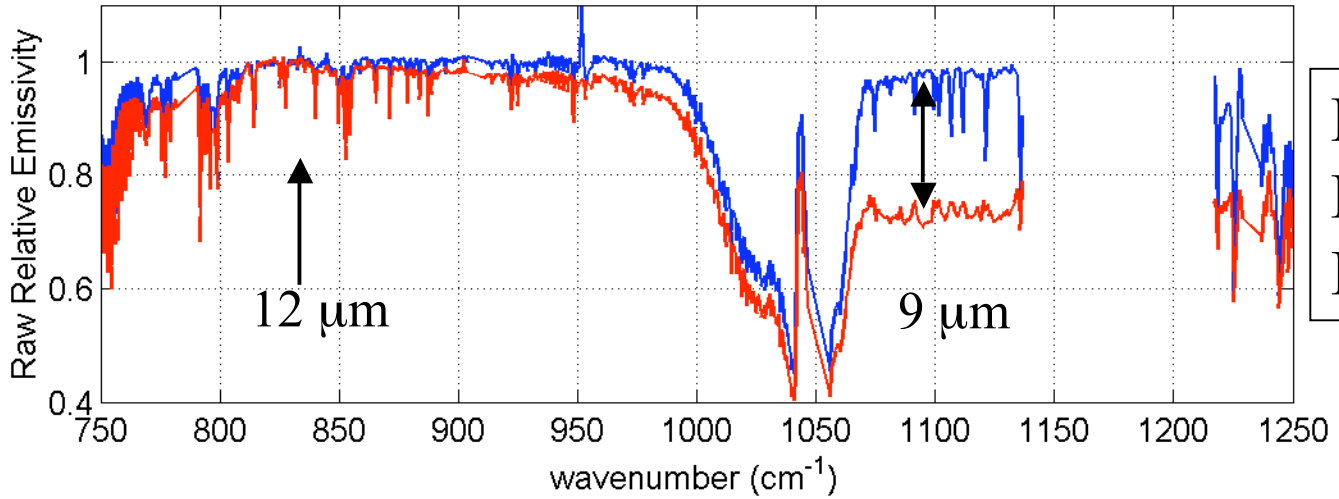
Daytime Overpass: 11:03 UTC on 16 Nov. 2002

AIRS Spectral Relative Emissivity: Egypt One



OBS. B.T. (K)

$$\frac{R_{obs}}{B(T_{12\mu m})}$$

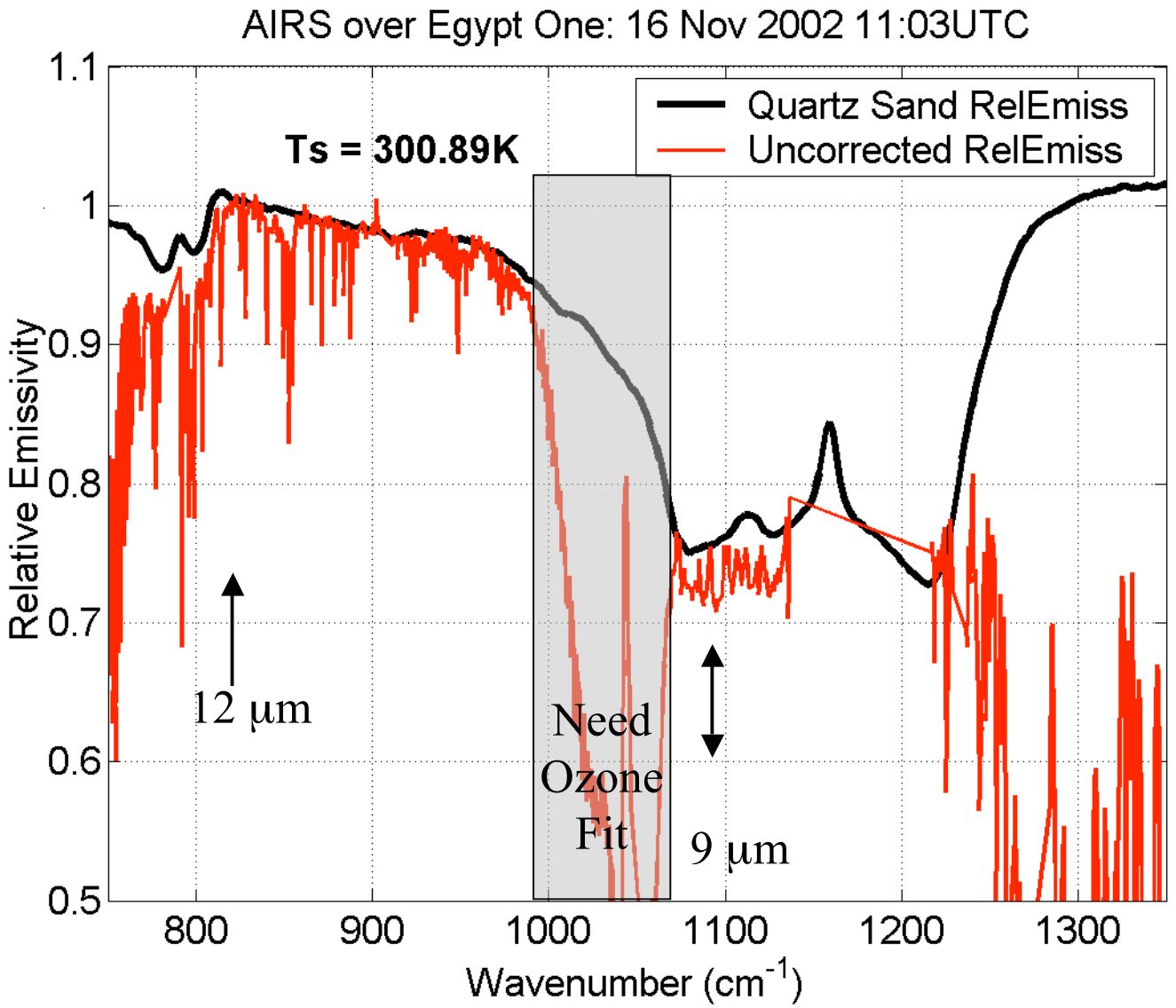


Raw Relative Emissivity

- Desert observations show strong Quartz restrahlung features.

RELATIVE Emissivity from Clear AIRS Obs.

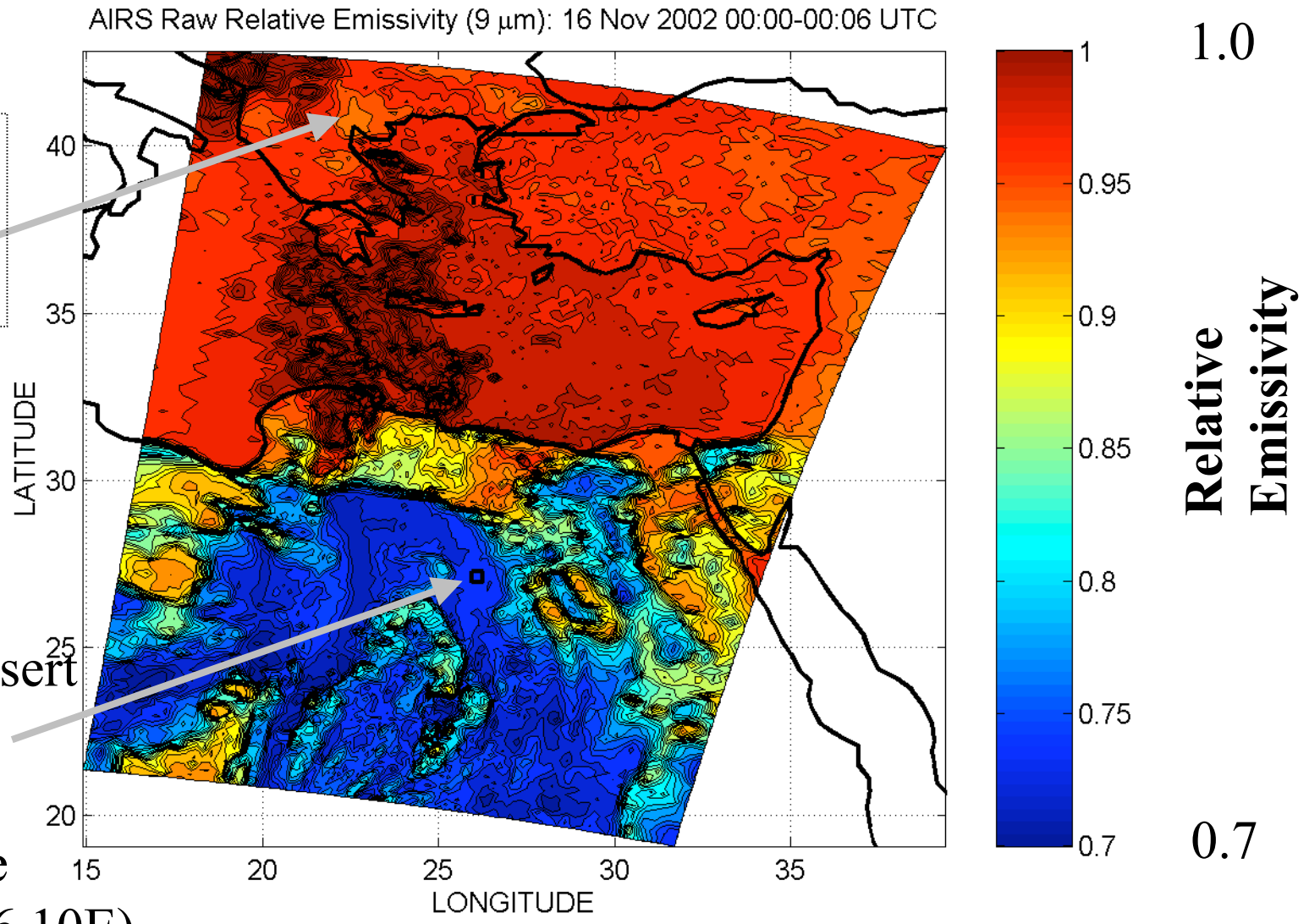
$$\frac{R_{obs}}{B(T_{12\mu m})}$$



Raw Relative Emissivity

- Relative emissivity contains atmospheric absorption lines.

NIGHT -- 9 μm relative to 12 μm

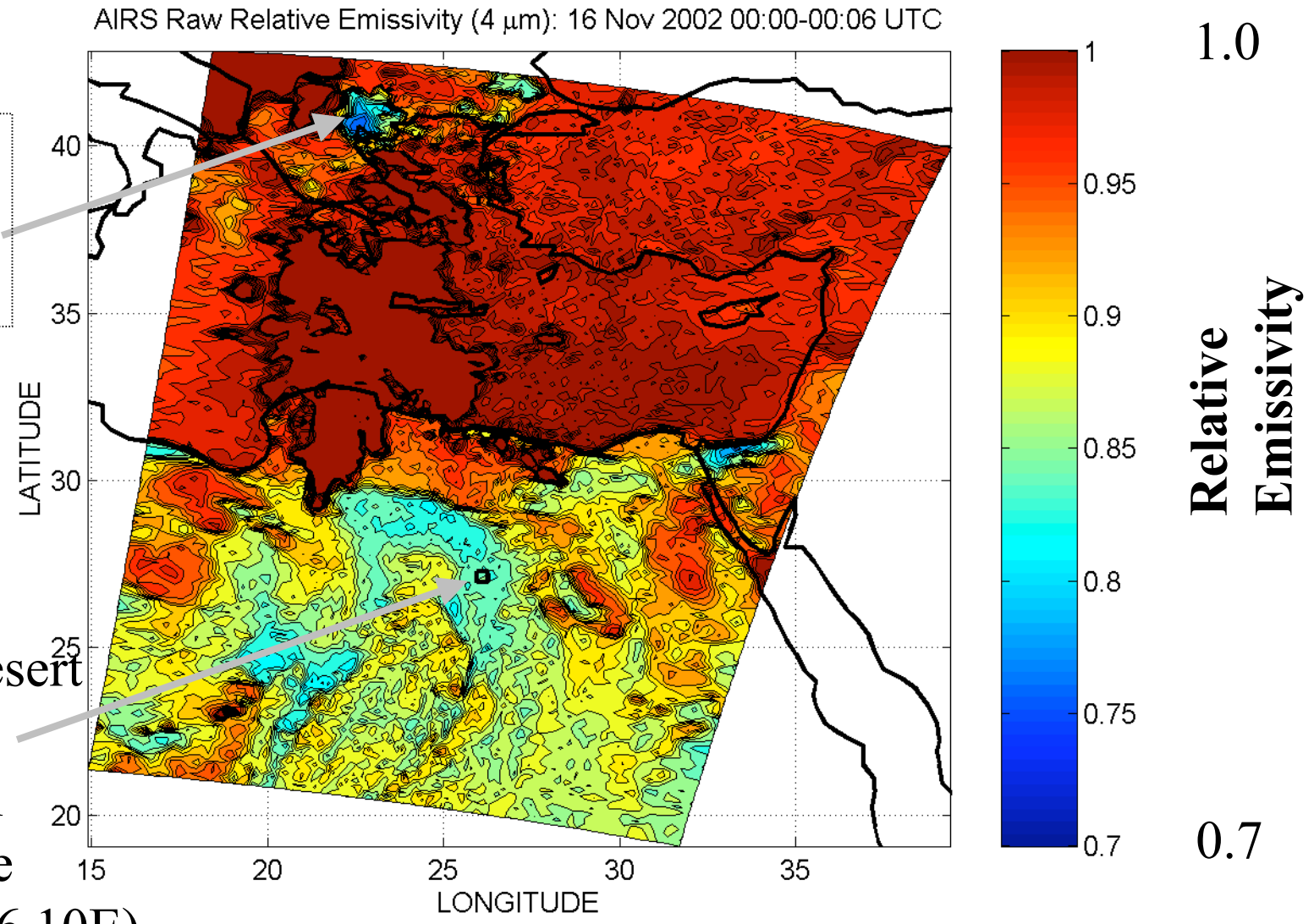


Thessaly Plain, Greece

Libyan Desert Satellite Validation Target Site (27.12N,26.10E)

16 November 2002 00:00-00:06 UTC (15-km FOV)

NIGHT -- 4 μm relative to 12 μm



Thessaly Plain, Greece

Libyan Desert Satellite Validation Target Site (27.12N,26.10E)

16 November 2002 00:00-00:06 UTC (15-km FOV)

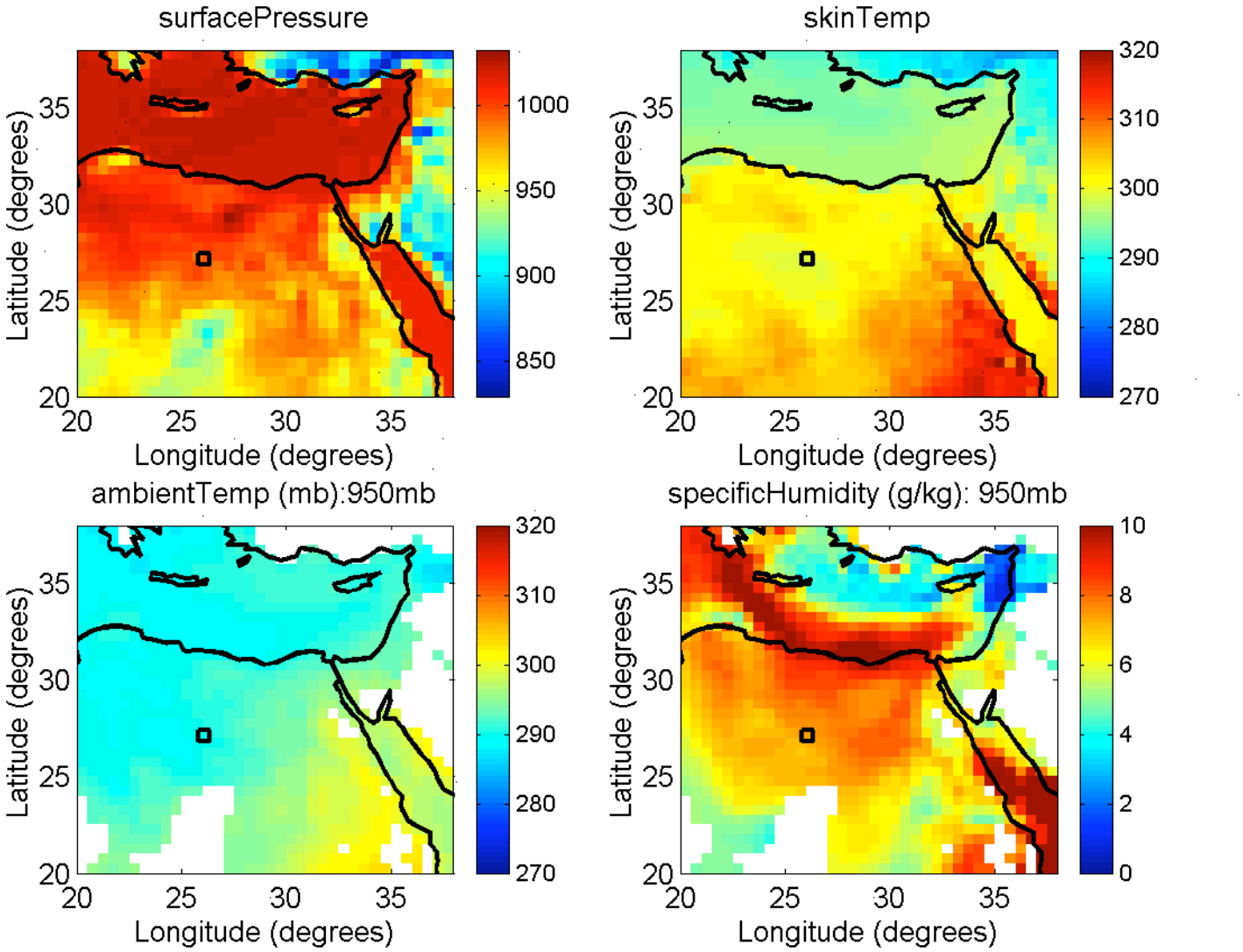
AIRS Absolute Emissivity and Surface Temperature (including Surface Reflection)

16 November 2002

Focus Day

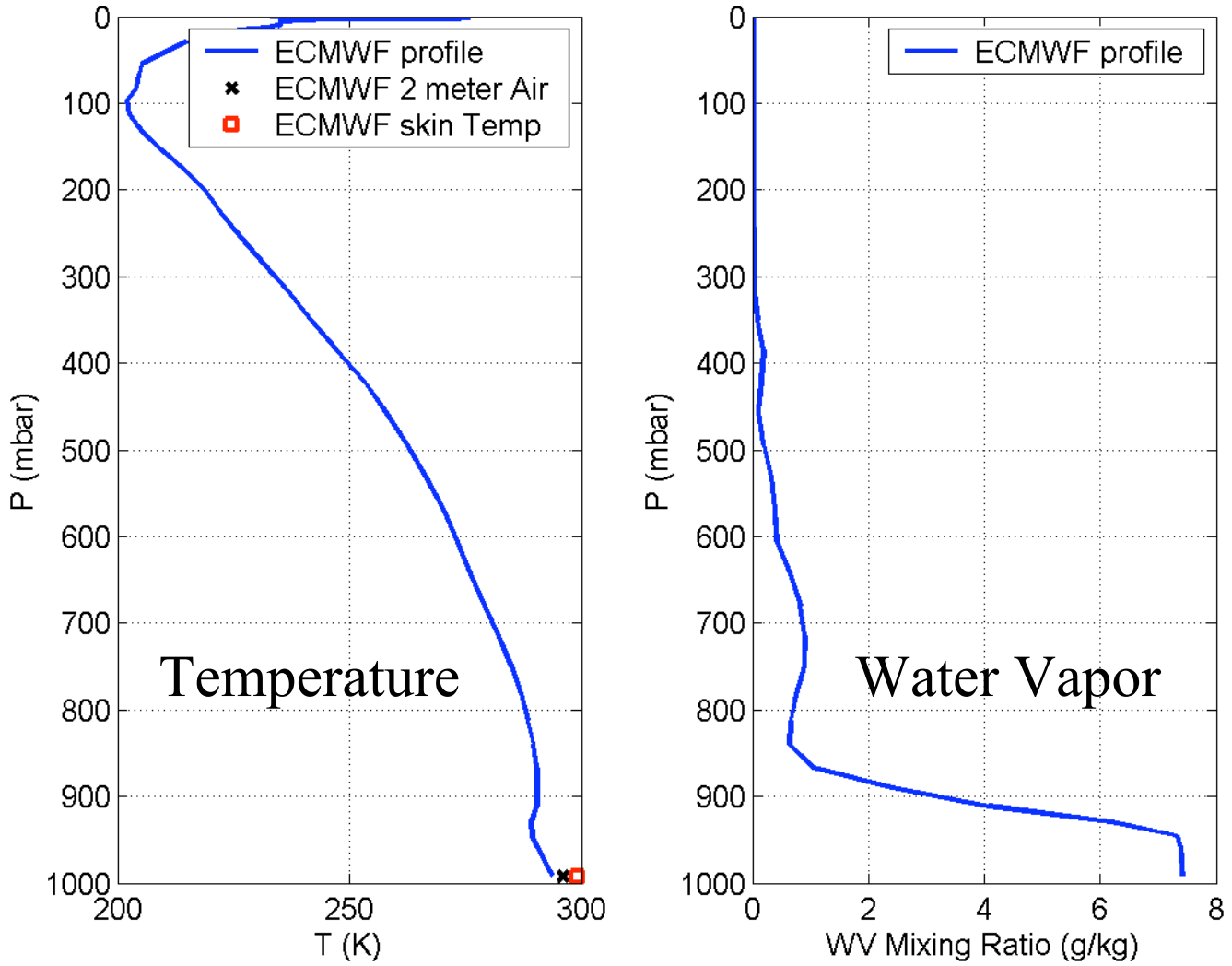
Technique follows that described in Knuteson, et al., Adv. Space Res., 33 (2004) 1114-1119.

ECMWF Analysis: 16 Nov. 2002 12 UTC



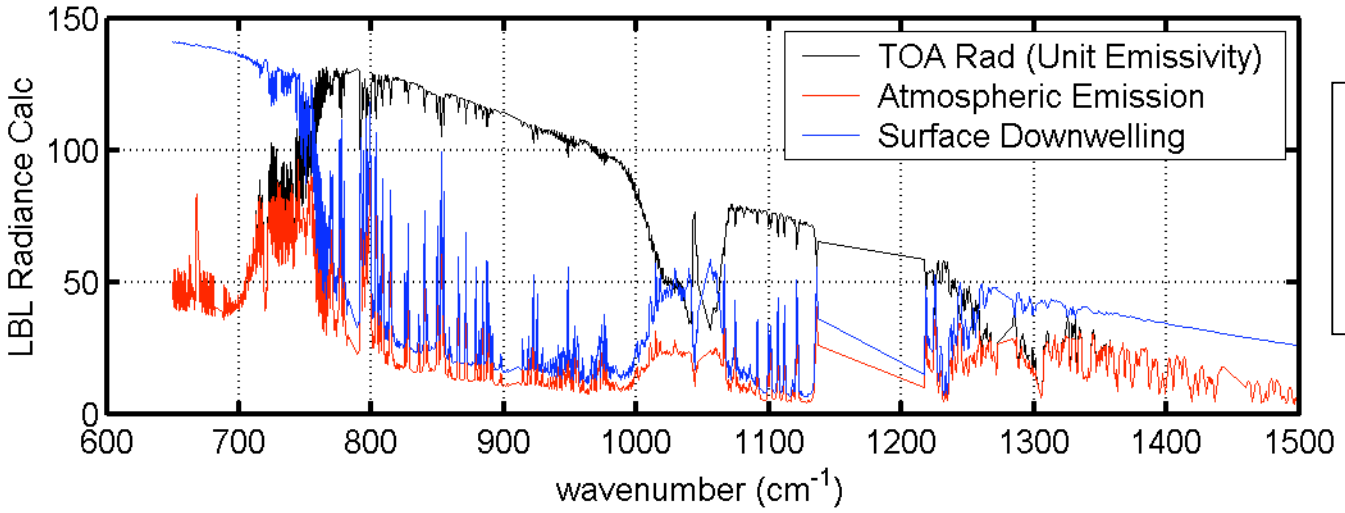
- Square symbol marks Egypt One site in Libyan Desert

ECMWF Analysis: 16 Nov. 2002 12 UTC

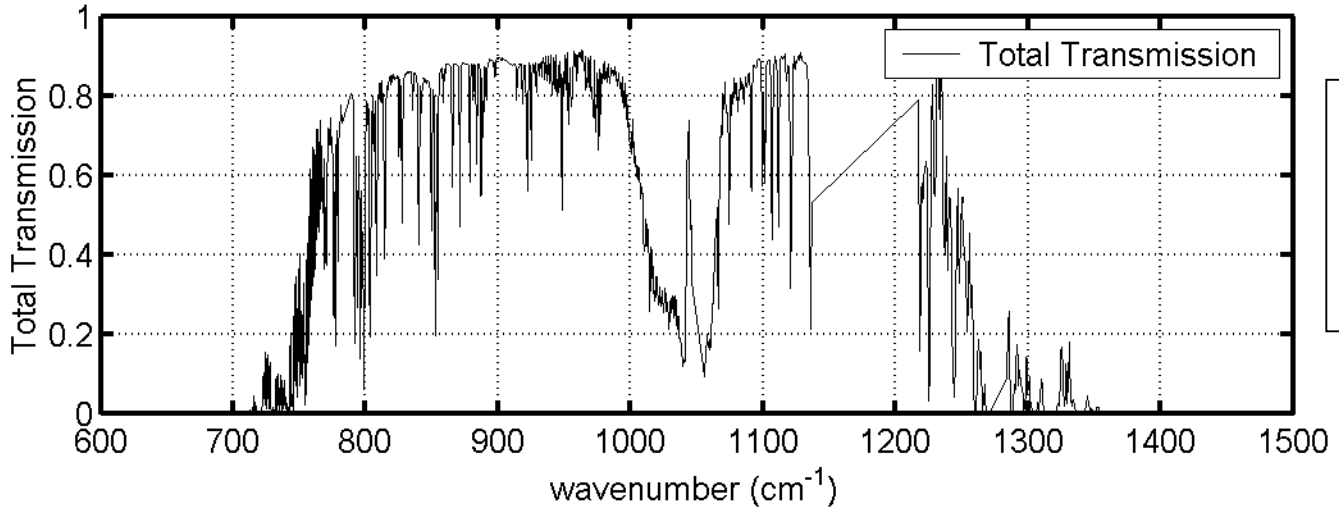


- ECMWF profile over Egypt One site in Libyan Desert

LBL Calculation Using ECMWF Model Profile



Up Down Radiance

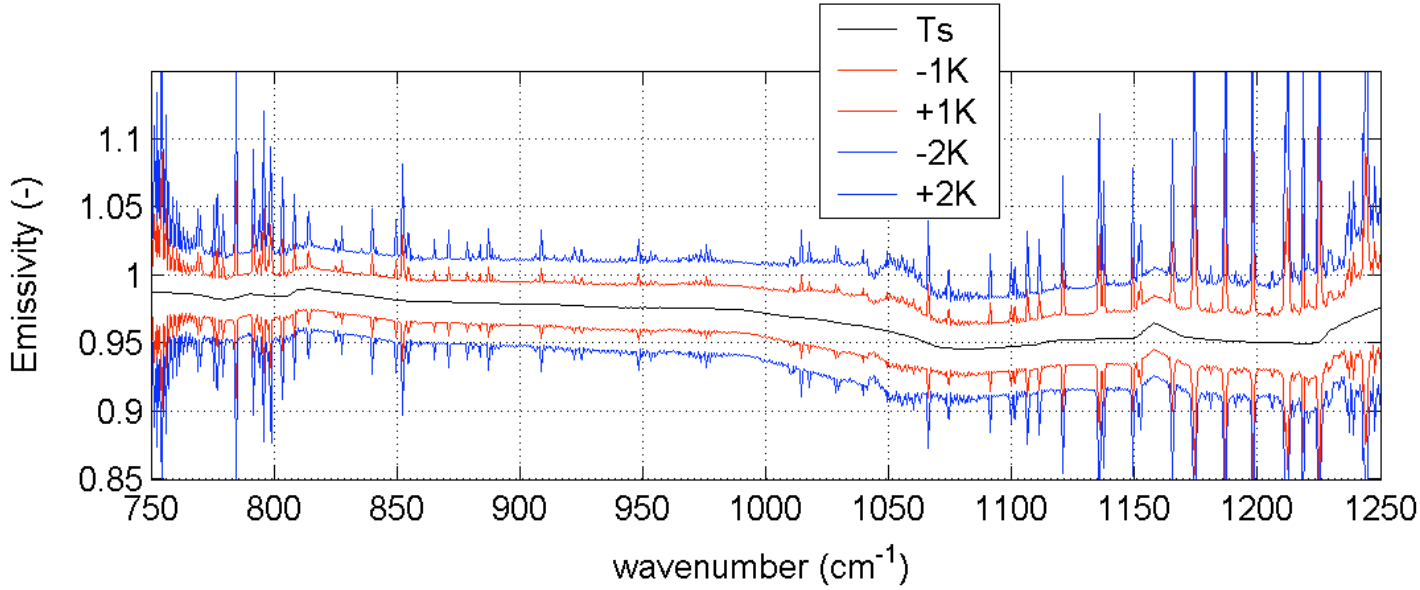


Total Trans-mission

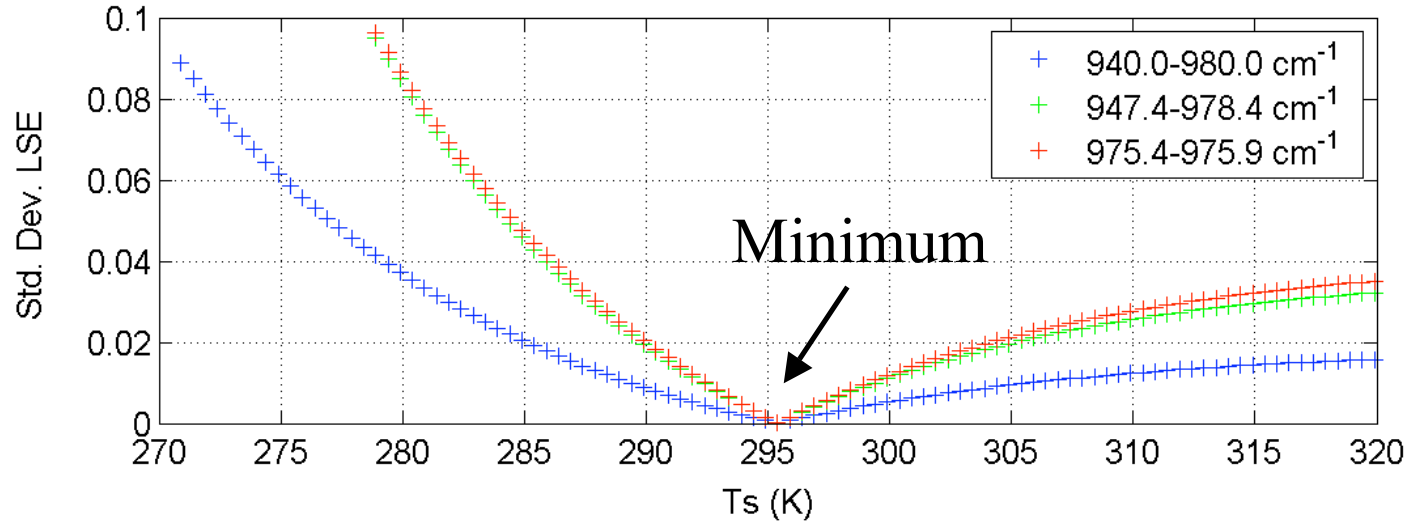
- LBLRTM calculations reduced to AIRS spectral resolution.

Constraint: Emissivity solution should be smoothly varying across atmospheric absorption lines!

E_ν



Std. Dev. E(Ts)

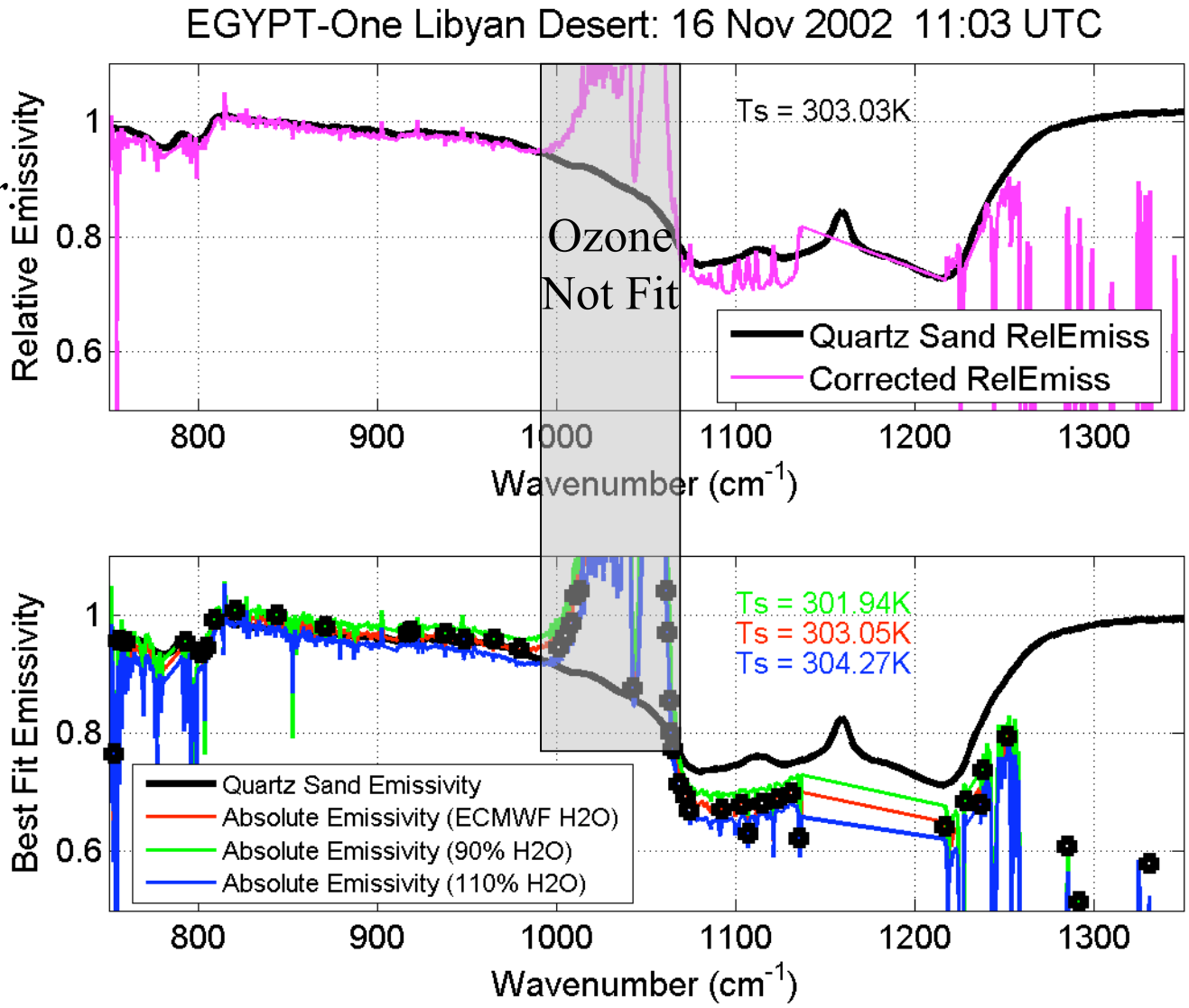


- Minimum Std. Deviation is at the true <u>skin temperature</u> !!

AIRS Absolute Emissivity

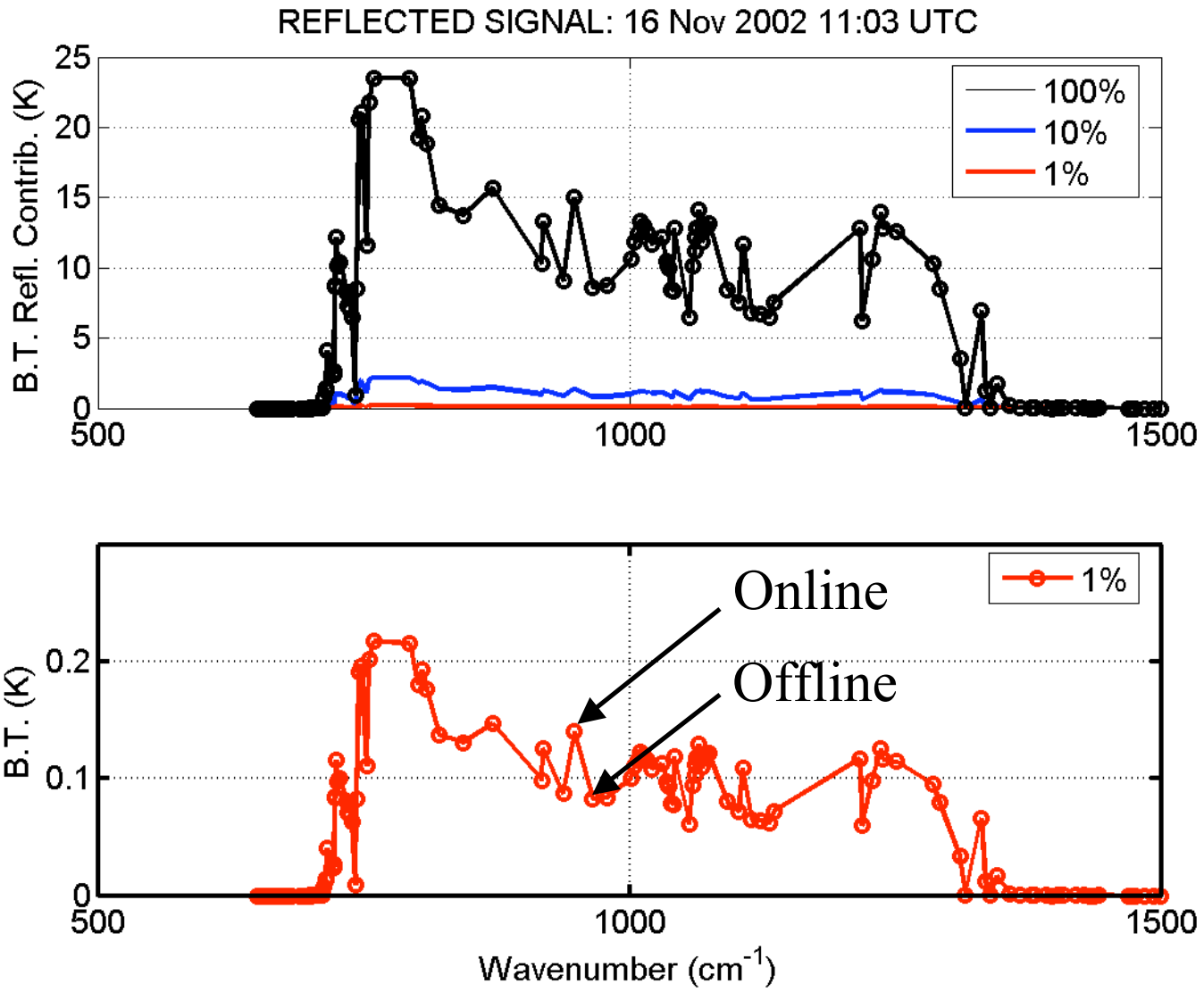
Atm. Corr. Relative IR Emiss

Absolute IR Emiss



- Squares are using 281 Select AIRS channels only. It Works !!!

How Good Does RTE Need to Be?



- Online/Offline Signal is 0.05K for a 1% reflectivity !!!

Clear Sky IR Emissivity from AIRS Summary

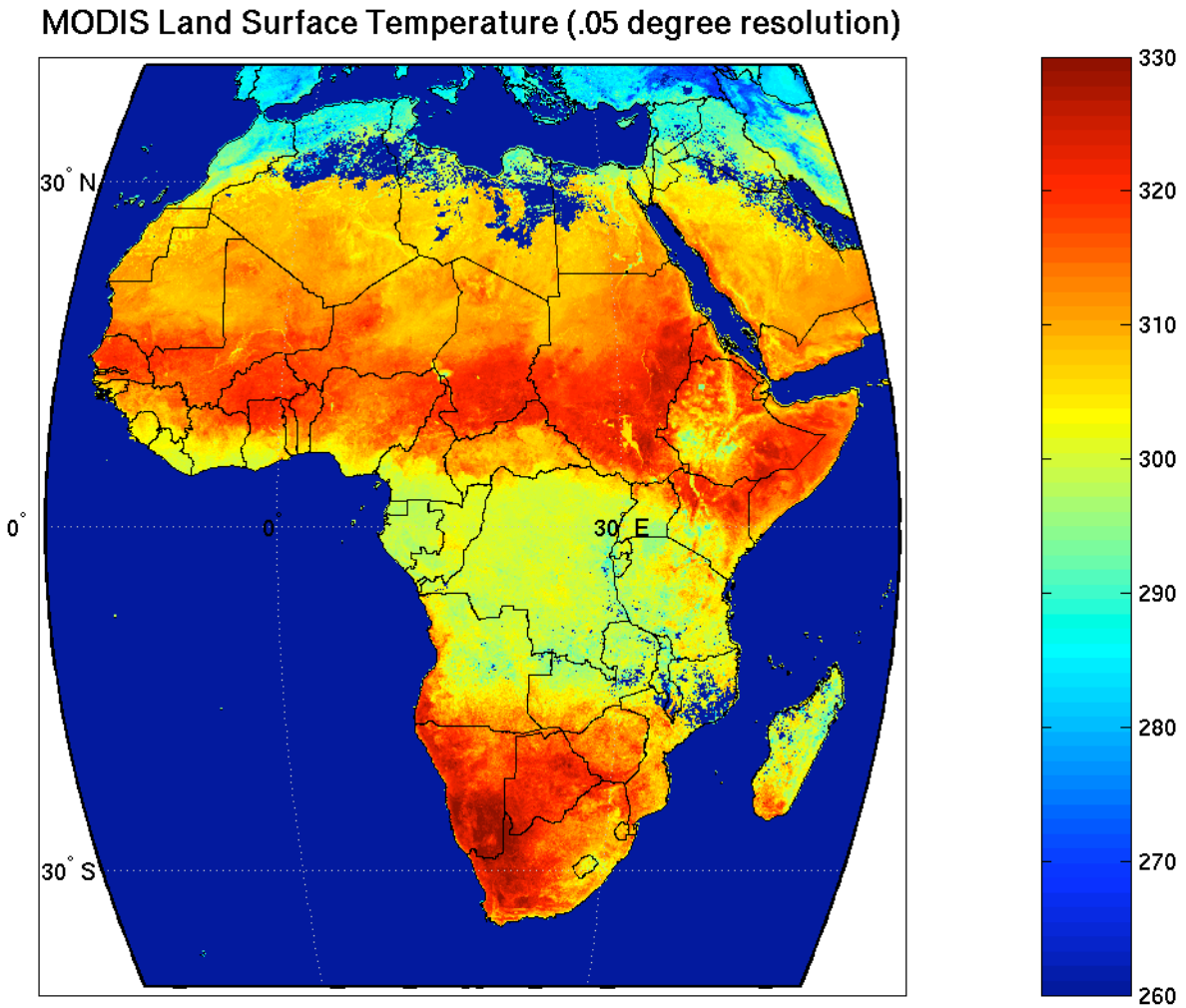
- Demonstrated ability to determine RELATIVE emissivity to within about 2% using ECMWF atmospheric state as input to a line-by-line RTE correction.
- Demonstrated ability to determine ABSOLUTE emissivity to about 1% using AIRS observations + ECMWF atmospheric temperature and water vapor profiles using Online/Offline technique. *(Assuming an accurate RTE model for reflection.)*
- Demonstrated that a 10% error in total water vapor leads to a 1% error in absolute emissivity with the On/Offline method.
- Demonstrated a FORTRAN implementation that gives consistent results using only the 281 channel subset. (!!!)
- Delivered FORTRAN code to JPL and JCDA for evaluation and possible routine implementation.

AIRS Surface Temperature and IR Emissivity Validation

AIRS/MODIS L3 Comparison

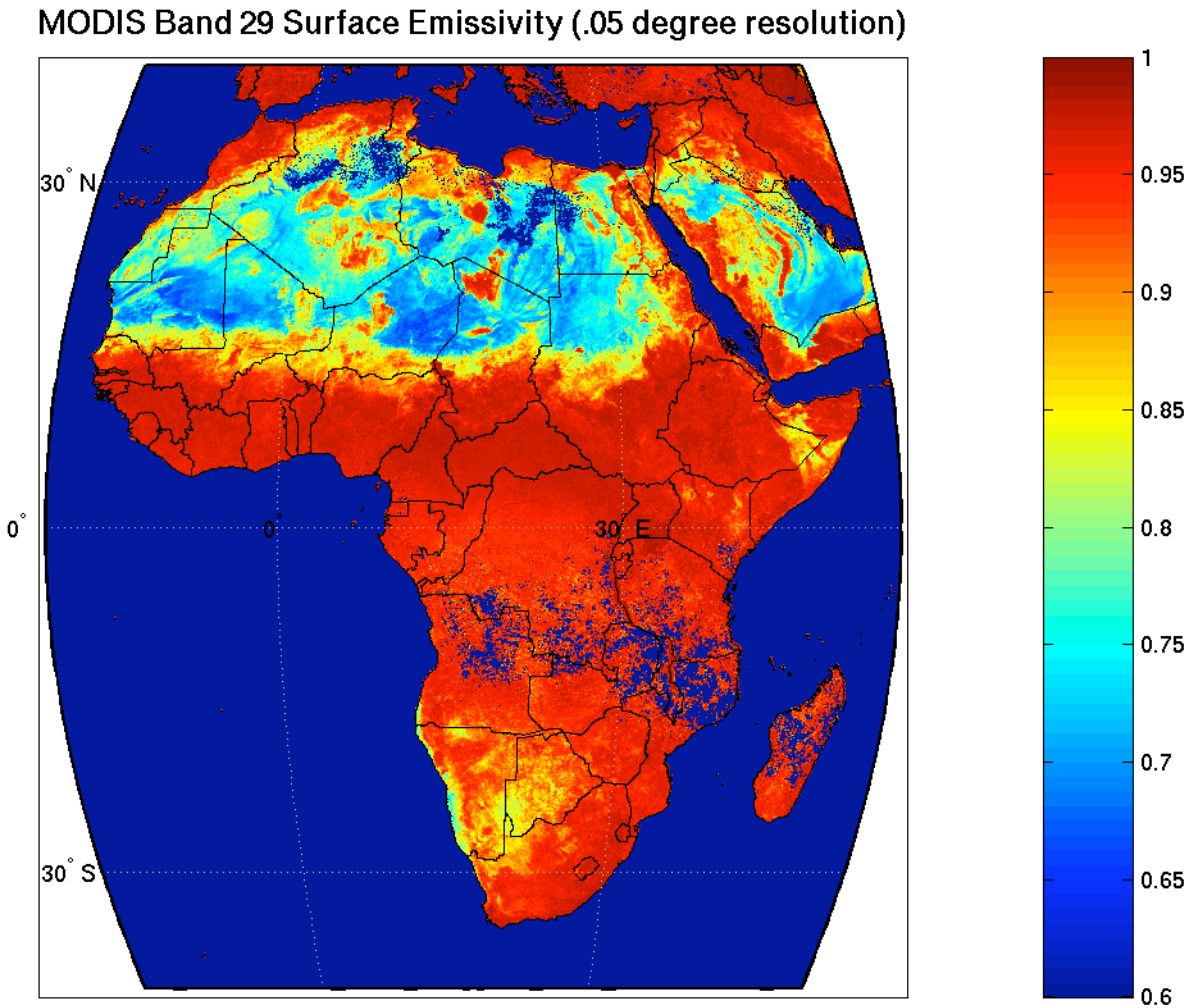
(Preliminary !!!)

MOD11 Monthly Composite



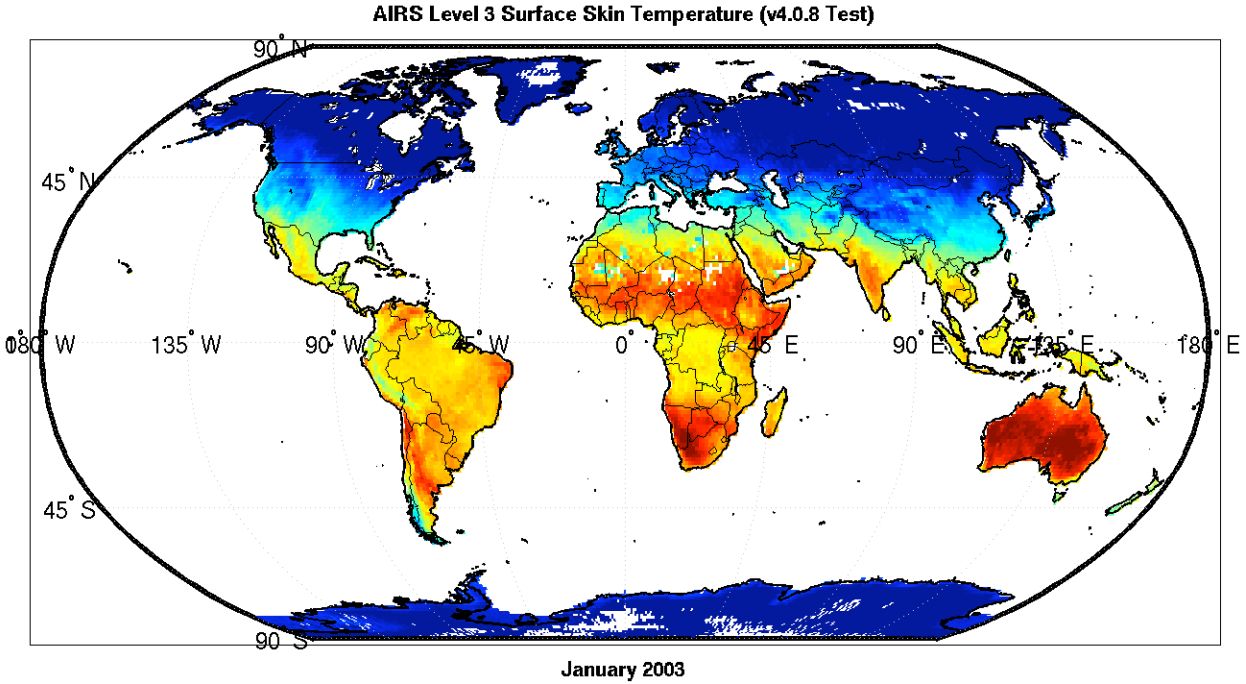
MODIS 0.05 deg (5 km) Land Surface Temperature

MOD11 Monthly Composite

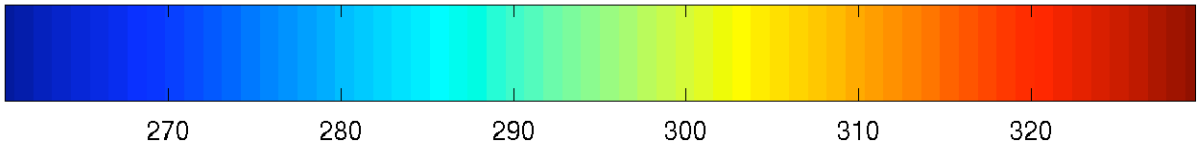


MODIS 0.05 deg (5 km) IR Emissivity at 8.5 μm

*** The AIRS L3 Product shown here is based on Release Version 3, which has NOT been validated over land. ***
(See Stephanie Granger's Talk Friday AM for more details.)



January 2003 Global Monthly Composite



AIRS 1 deg (100 km) Land Surface Temperature

AIRS Validation Against MODIS Products (or vice versa)

Method:

1. Degrade MOD11 product from 5 km (0.05 deg) to 100 km (1 degree) bins by taking the median value.
2. Difference AIRS L3 and degraded MOD11 products.
3. Display difference maps and histograms for
   a) Land Surface Temperature
   b) IR Emissivity (12, 8.5, and 3.9 μm)
4. Display Time Series of Monthly Tskin Differences on regional scales.

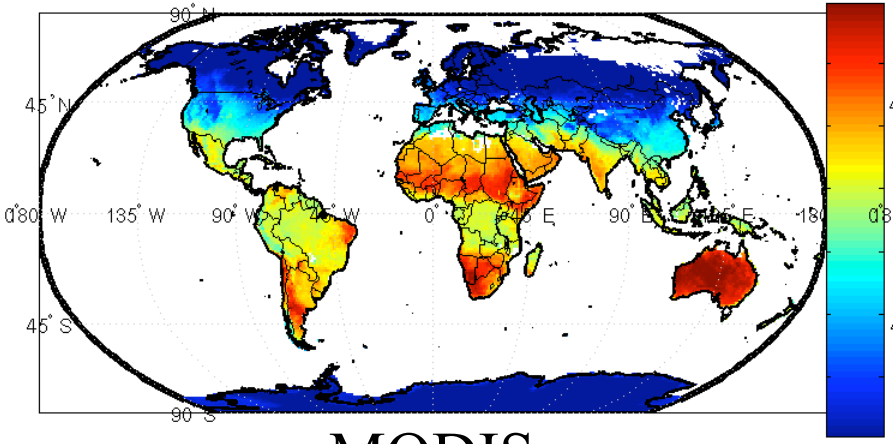
This comparison method is suggested for future evaluation of AIRS land surface temperature products since it can be used to identify potential problem areas in either the AIRS or MODIS products.

Skin Temperature

January 2003

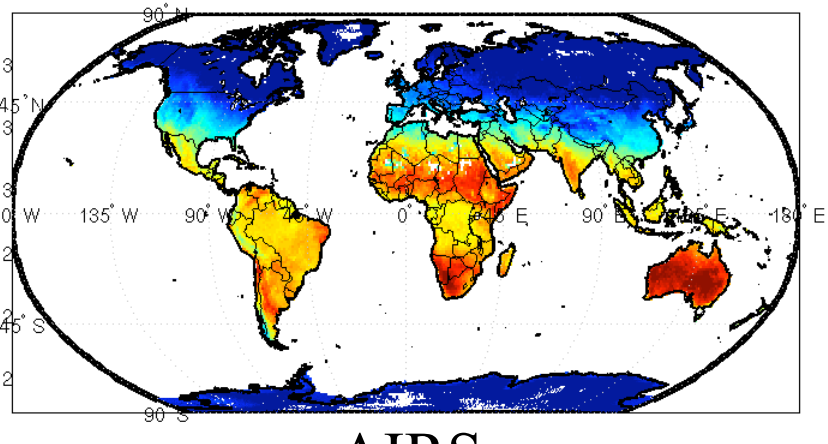
January 2003

MODIS (v4) Surface Skin Temperature (1 degree resolution)



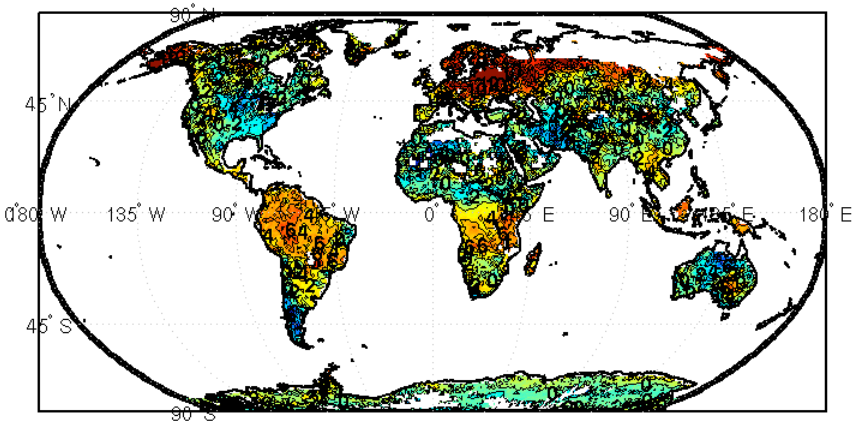
MODIS

AIRS Level 3 Surface Skin Temperature (v4.0.8 Test)

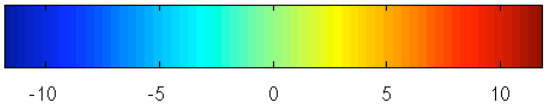


AIRS

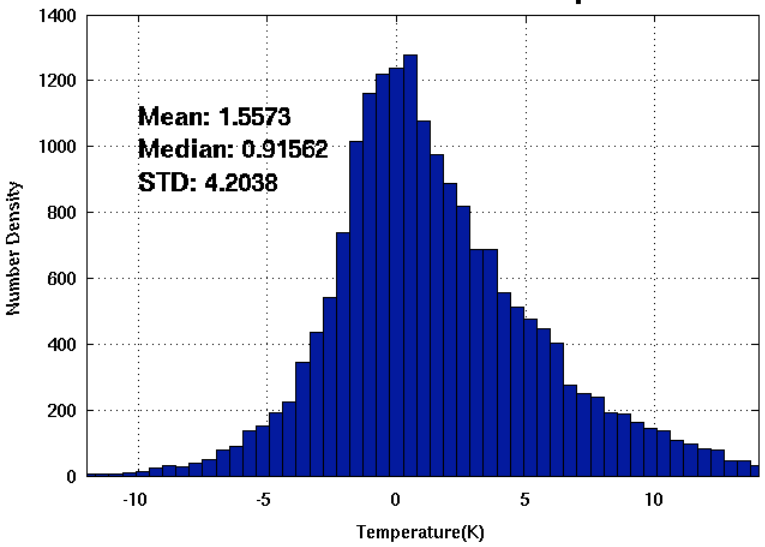
AIRS minus MODIS Surface Skin Temperature



AIRS - MODIS



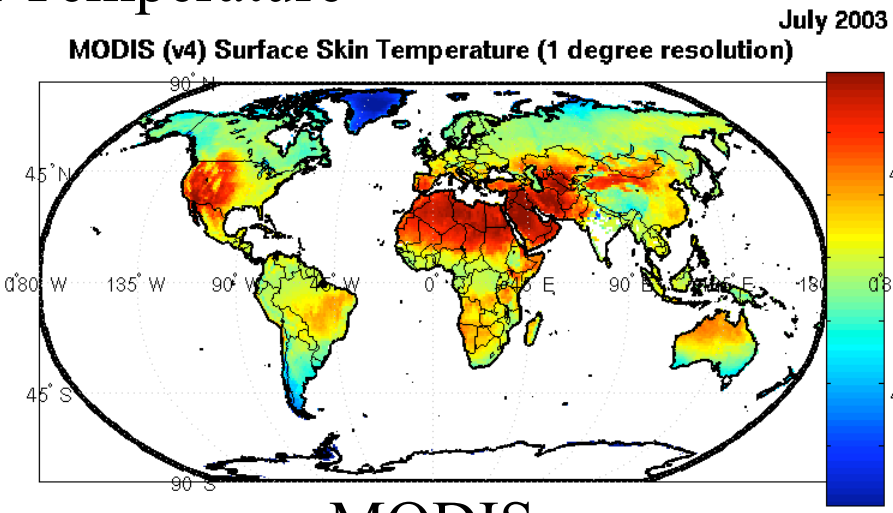
AIRS L3 minus MODIS Land Surface Skin Temperature Distribution



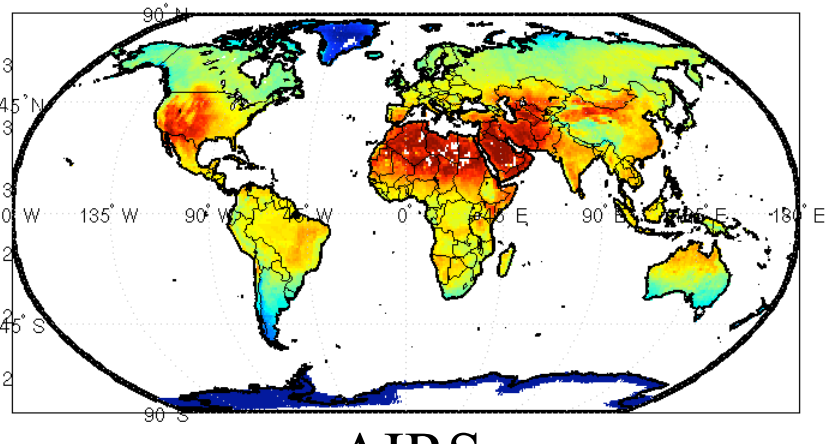
Created at UW-SSEC on 22-Apr-2005

Skin Temperature

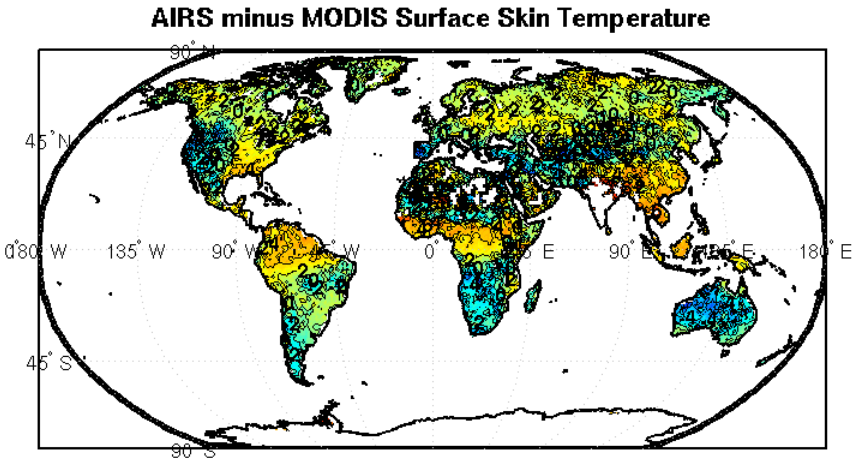
July 2003



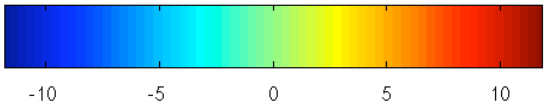
MODIS

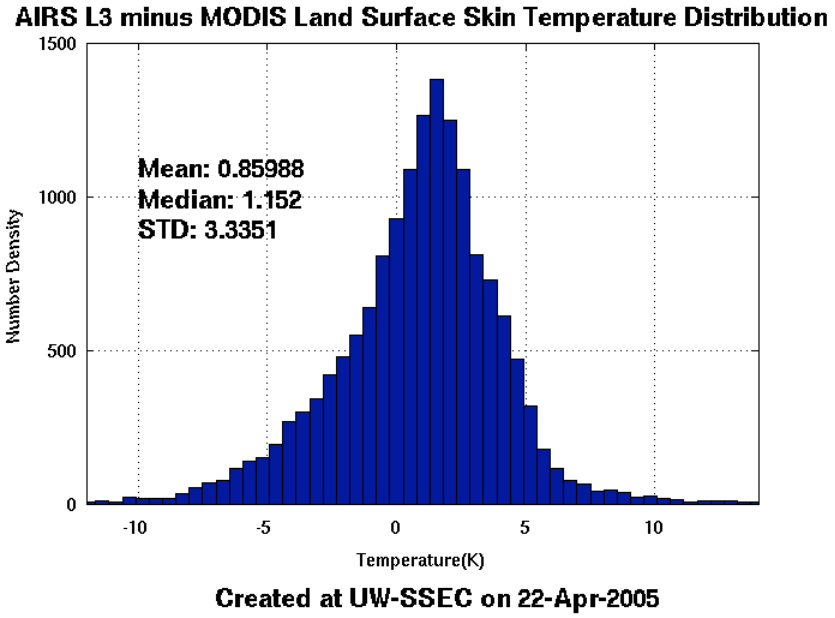


AIRS



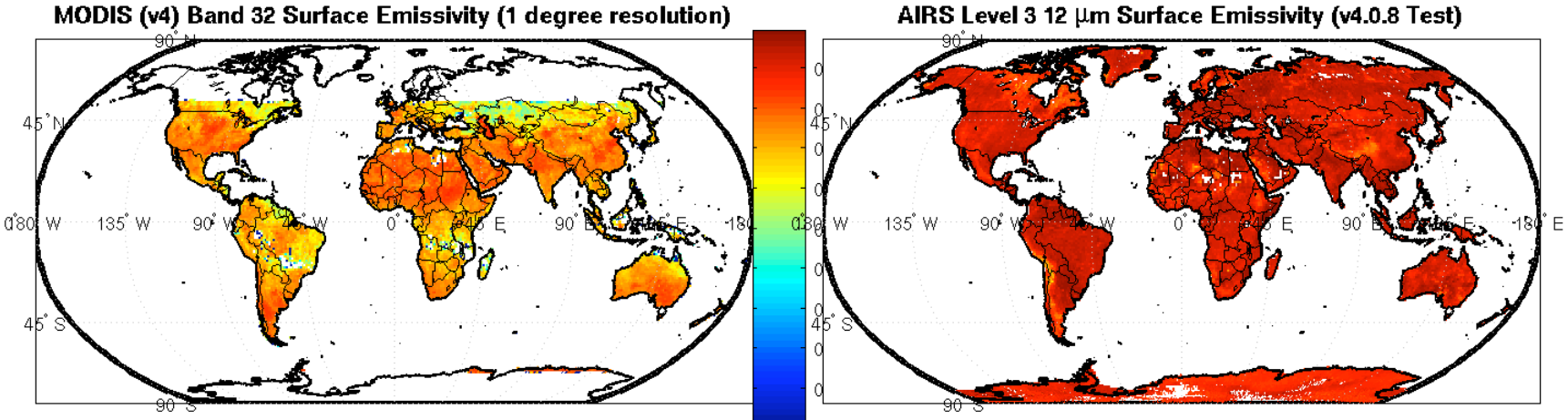
AIRS - MODIS



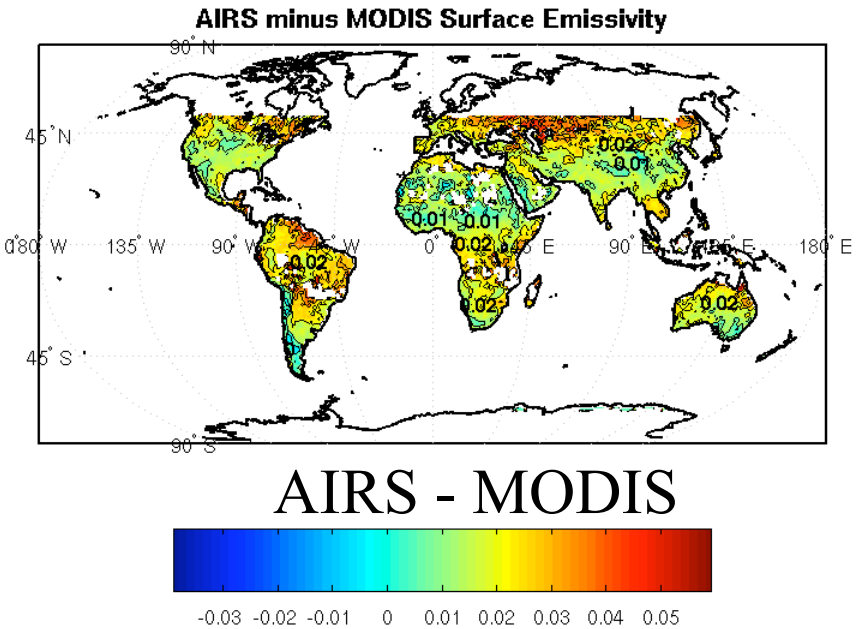


12 μm Emissivity

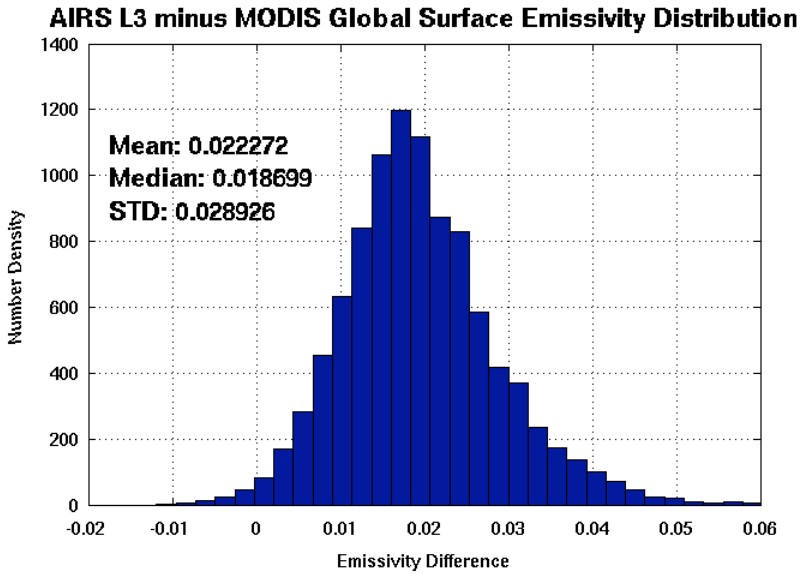
January 2003



MODIS AIRS

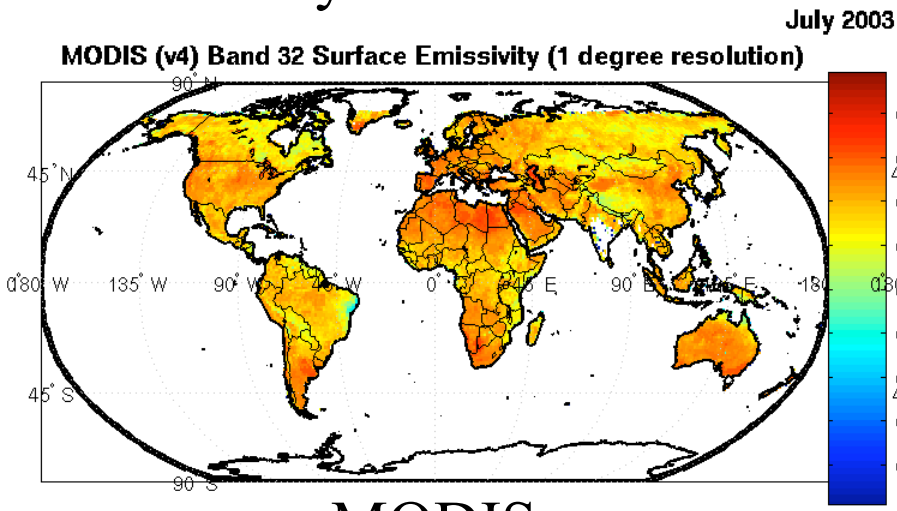


AIRS - MODIS

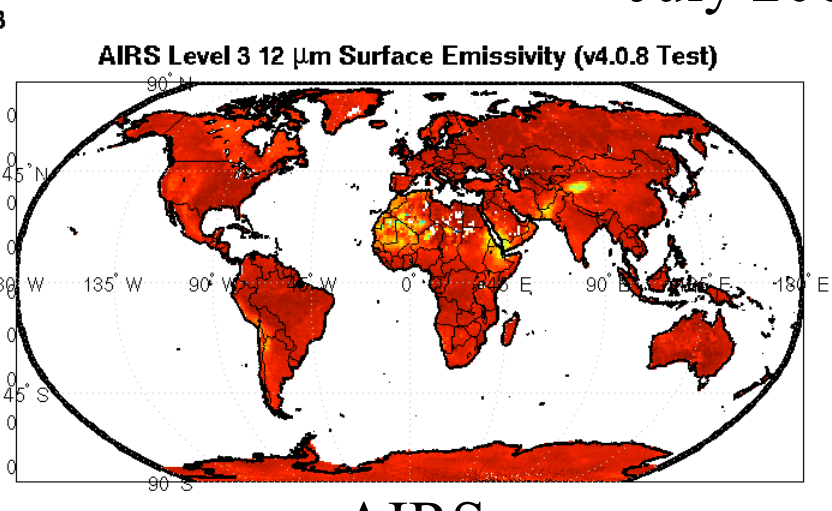


12 μm Emissivity

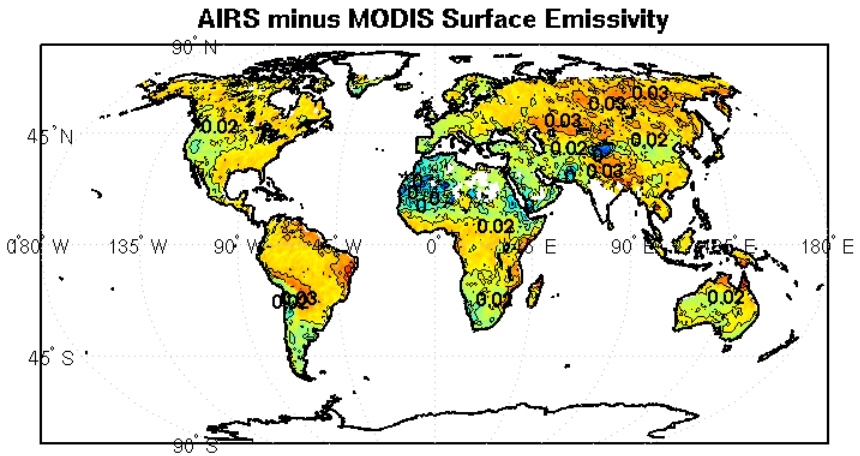
July 2003



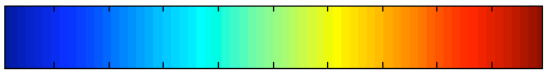
MODIS

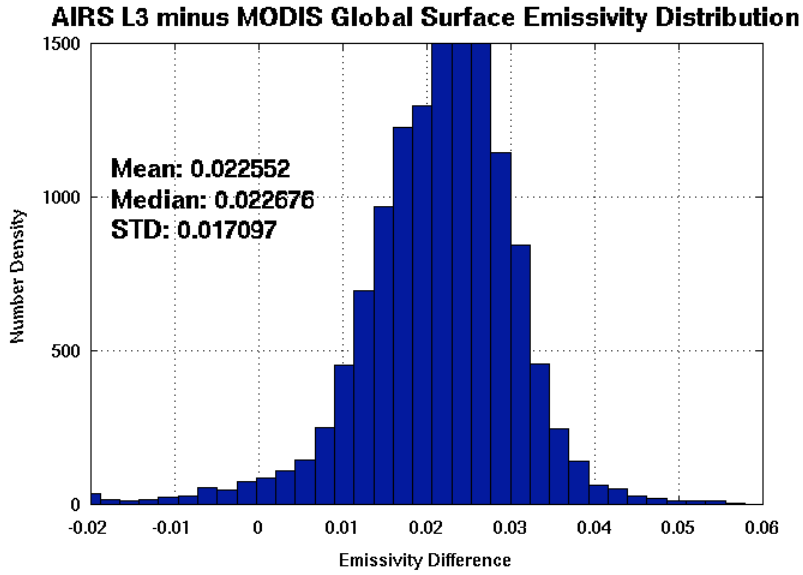


AIRS



AIRS - MODIS



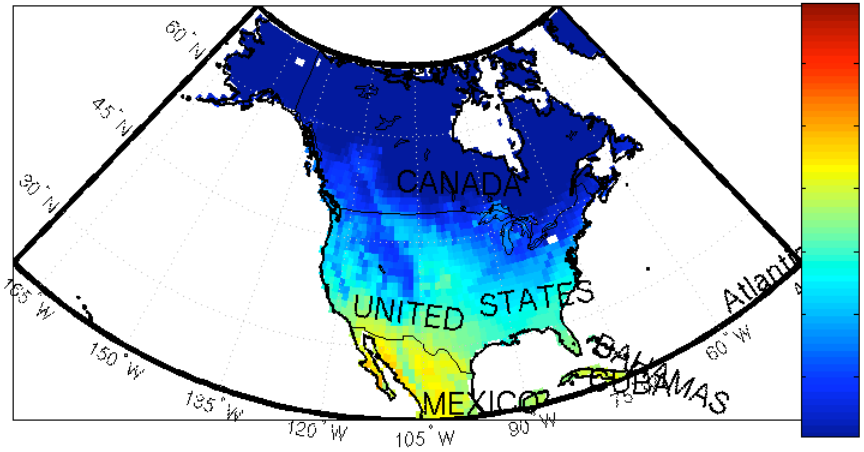


Skin Temperature

January 2003

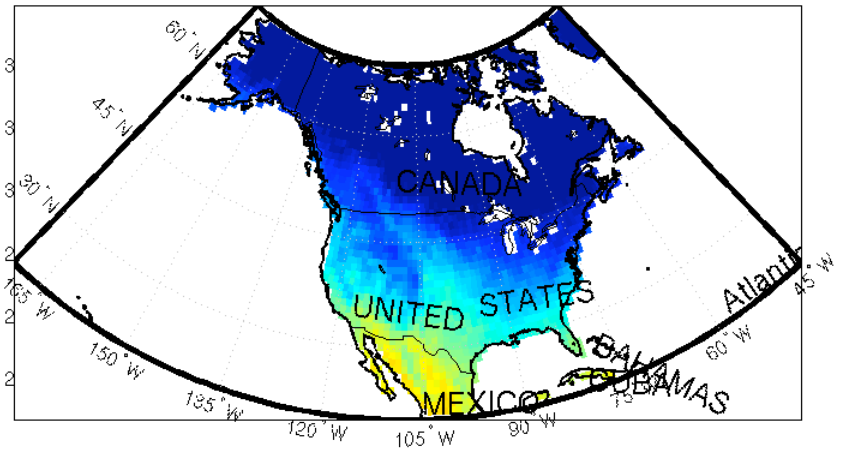
January 2003

MODIS (v4) Surface Skin Temperature (1 degree resolution)



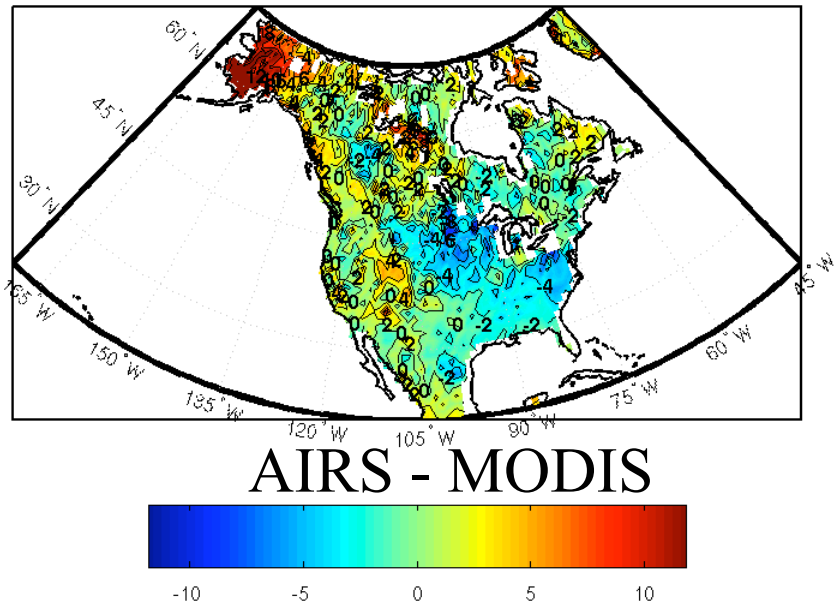
MODIS

AIRS Level 3 Surface Skin Temperature (v4.0.8 Test)



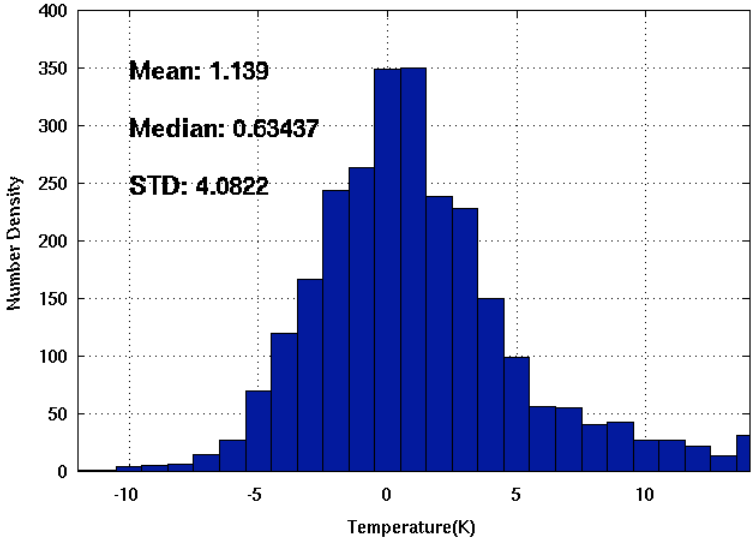
AIRS

AIRS minus MODIS Surface Skin Temperature



AIRS - MODIS

AIRS L3 minus MODIS Land Surface Skin Temperature Distribution



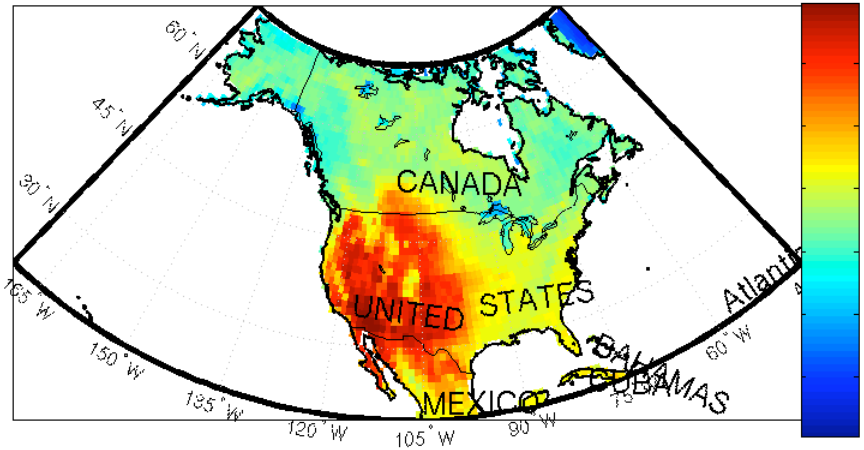
Created at UW-SSEC on 22-Apr-2005

Skin Temperature

July 2003

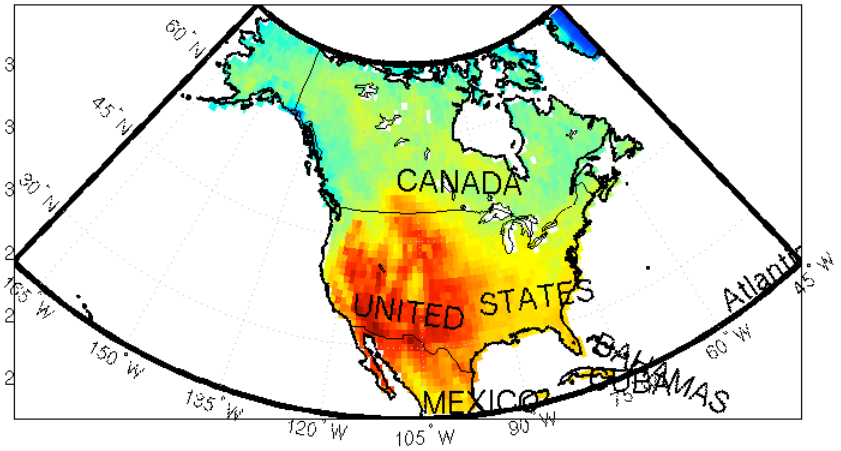
July 2003

MODIS (v4) Surface Skin Temperature (1 degree resolution)



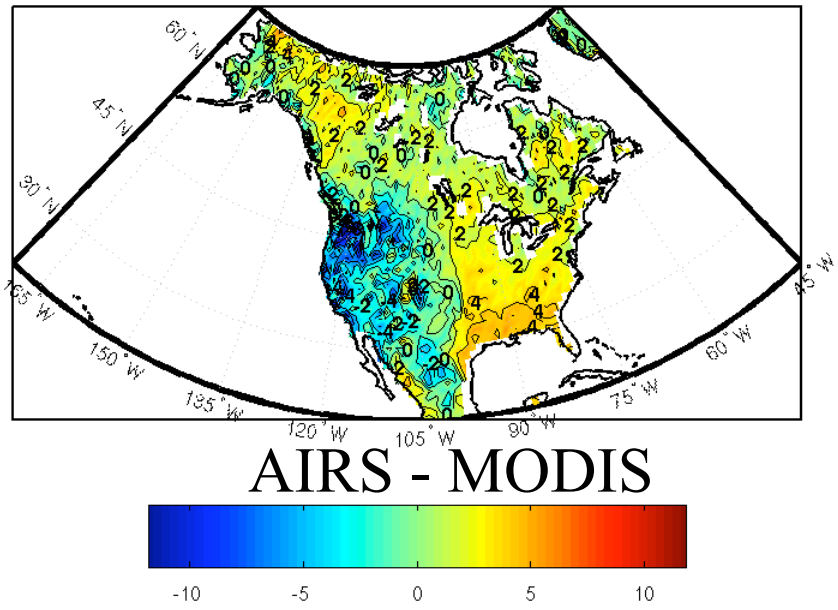
MODIS

AIRS Level 3 Surface Skin Temperature (v4.0.8 Test)



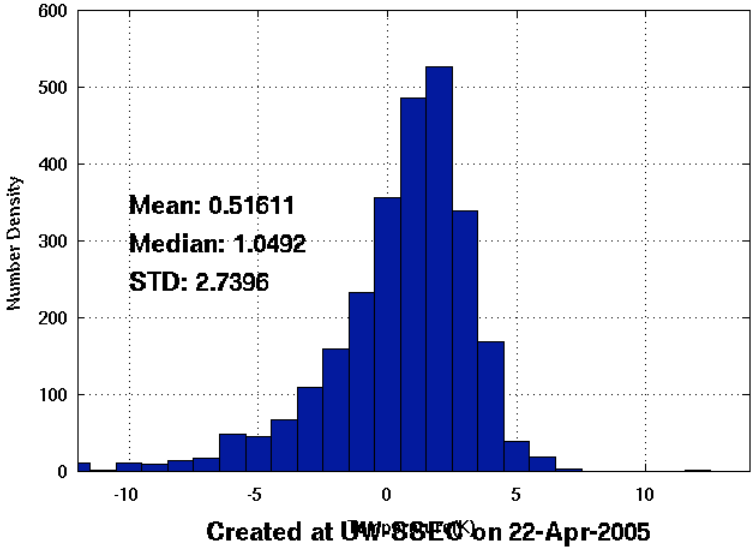
AIRS

AIRS minus MODIS Surface Skin Temperature



AIRS - MODIS

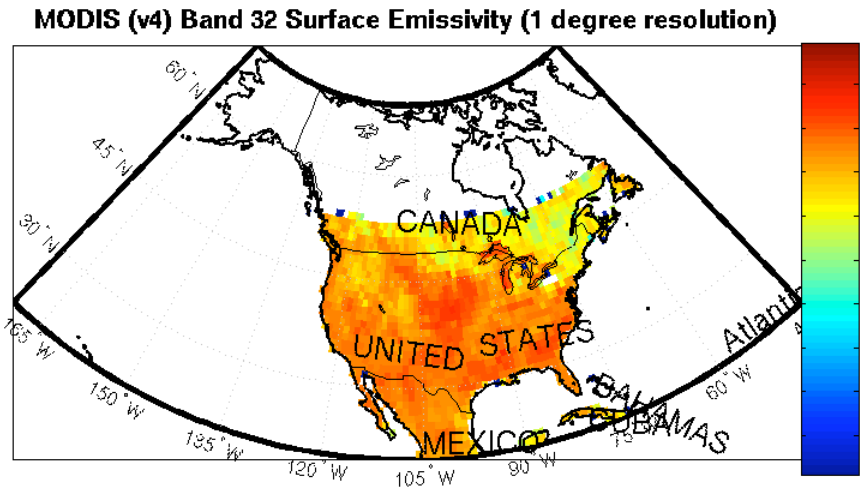
AIRS L3 minus MODIS Land Surface Skin Temperature Distribution



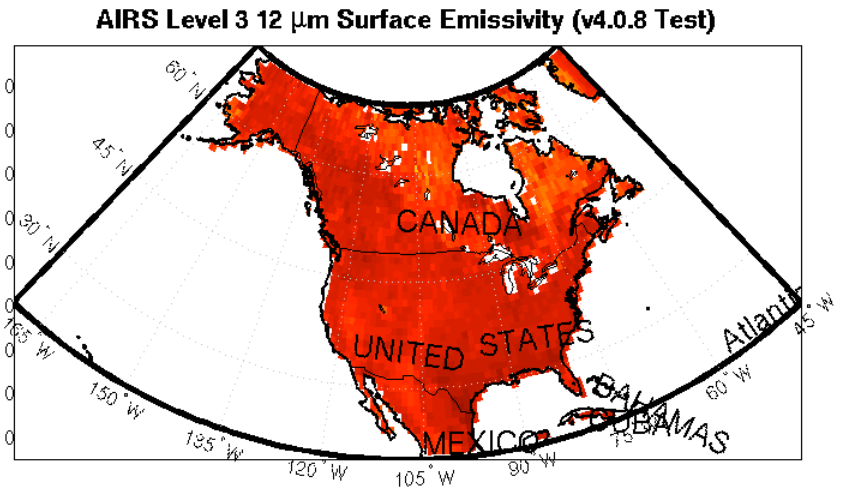
12 μm Emissivity

January 2003

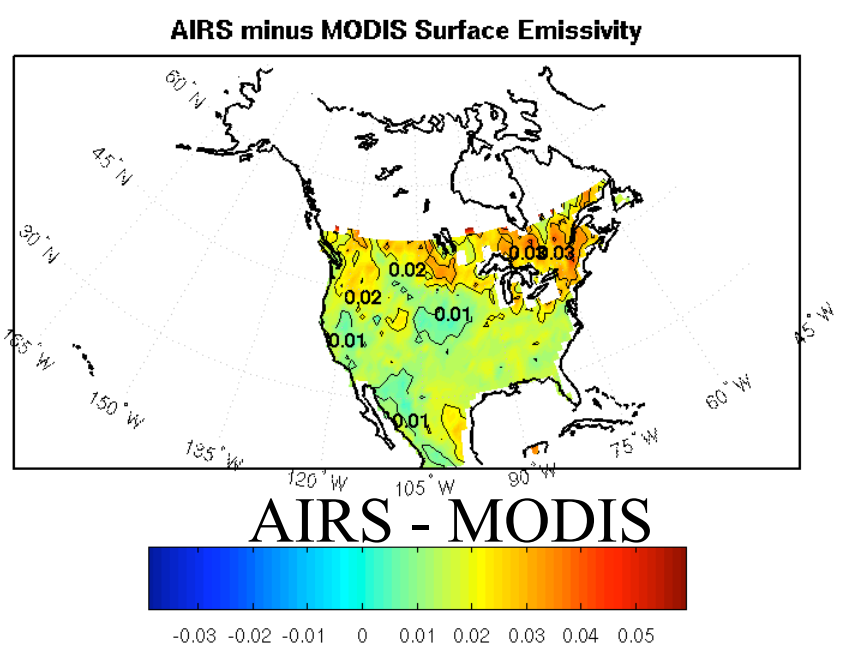
January 2003



MODIS



AIRS



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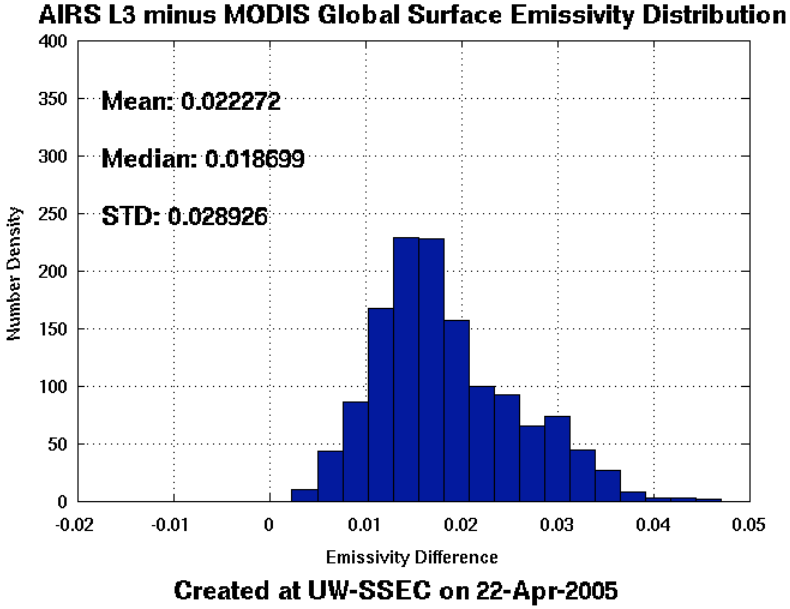
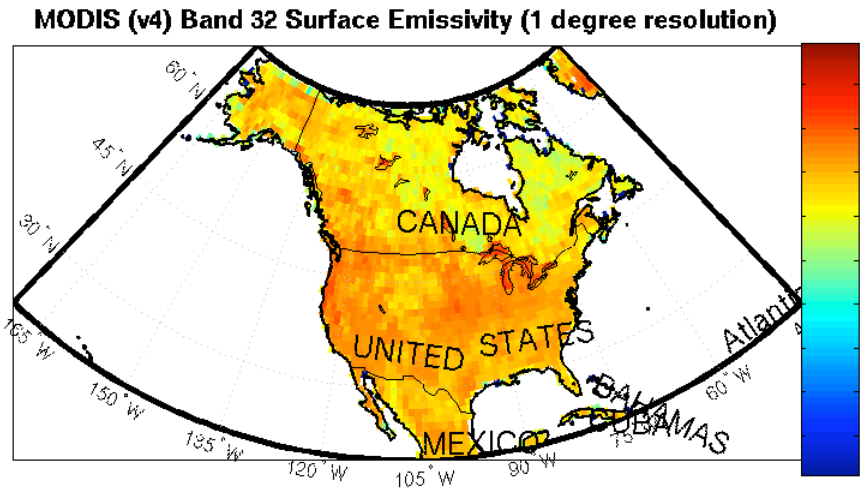


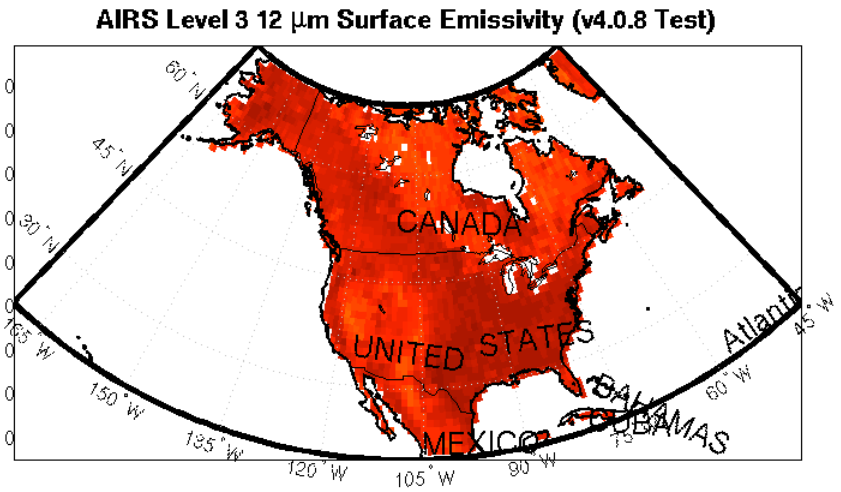
12 μm Emissivity

July 2003

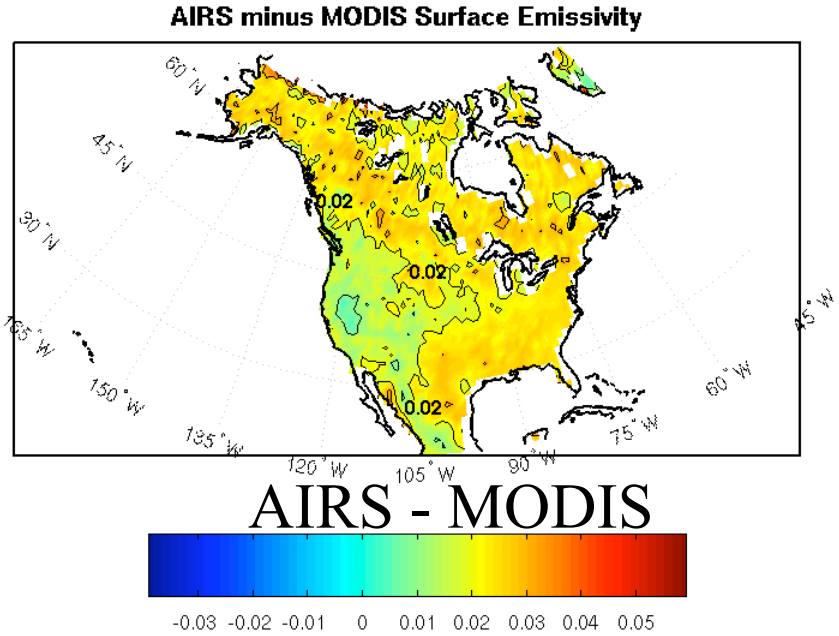
July 2003



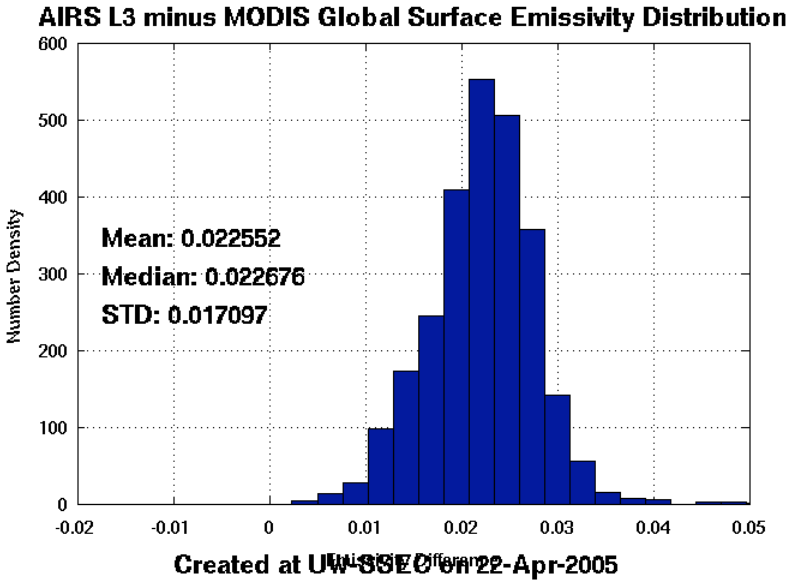
MODIS



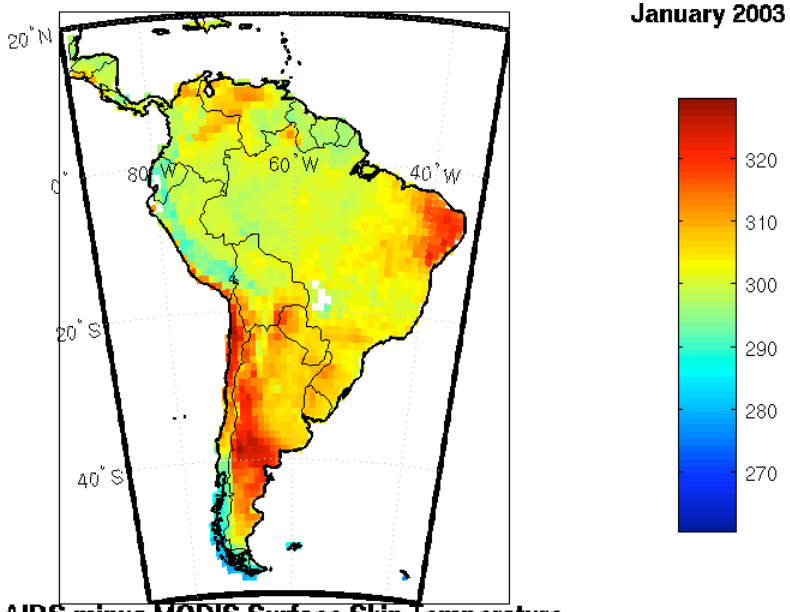
AIRS



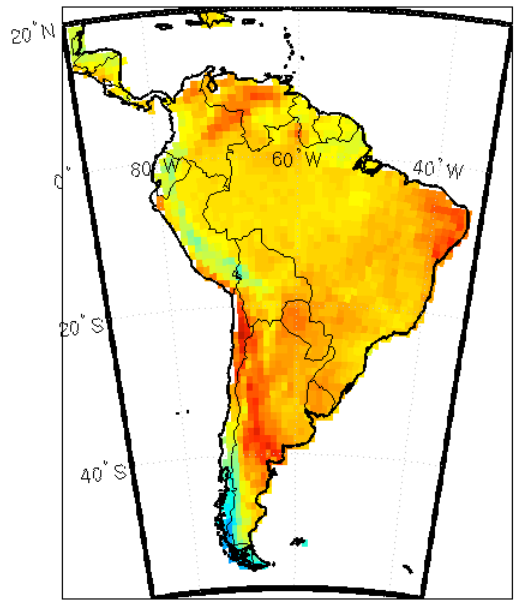
AIRS - MODIS



MODIS (v4) Surface Skin Temperature (1 degree resolution)

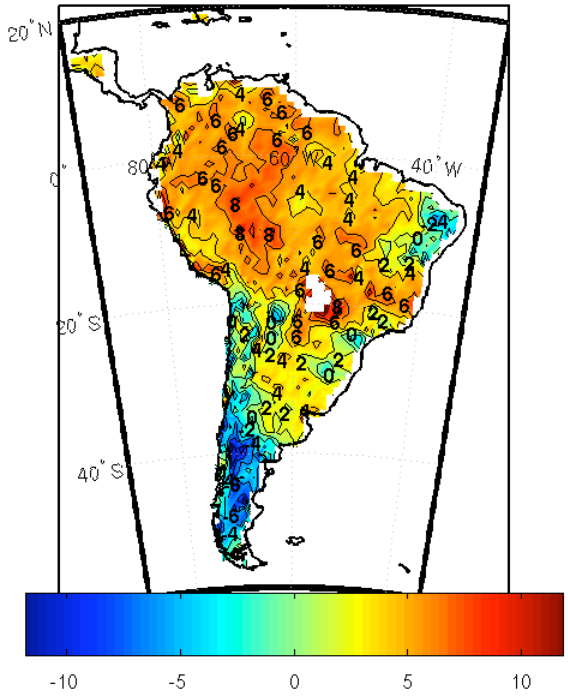


AIRS Level 3 Surface Skin Temperature (v4.0.8 Test)

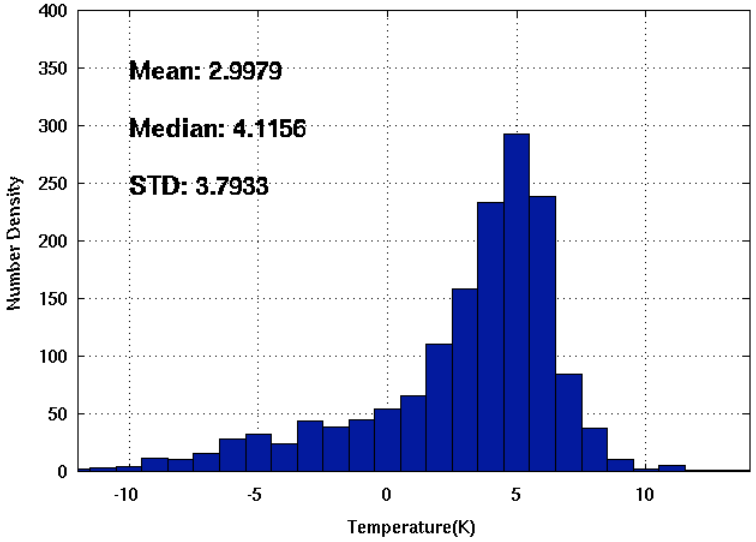


January 2003

AIRS minus MODIS Surface Skin Temperature



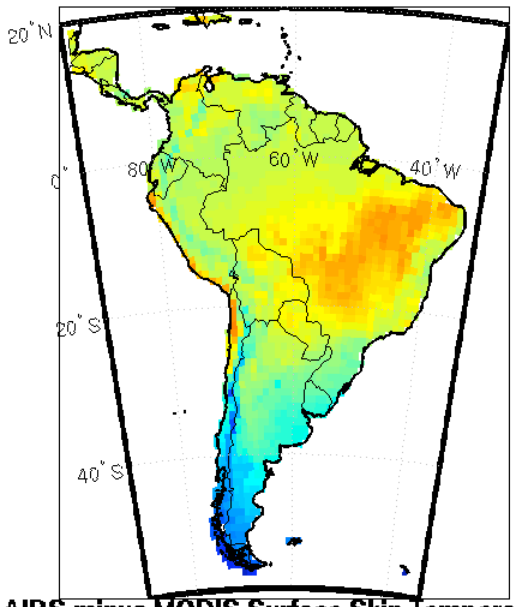
AIRS L3 minus MODIS Land Surface Skin Temperature Distribution

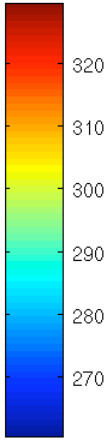


Created at UW-SSEC on 22-Apr-2005

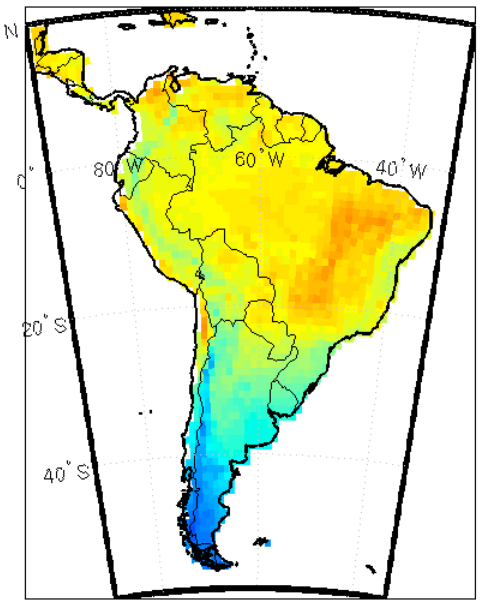
MODIS (v4) Surface Skin Temperature (1 degree resolution)

July 2003



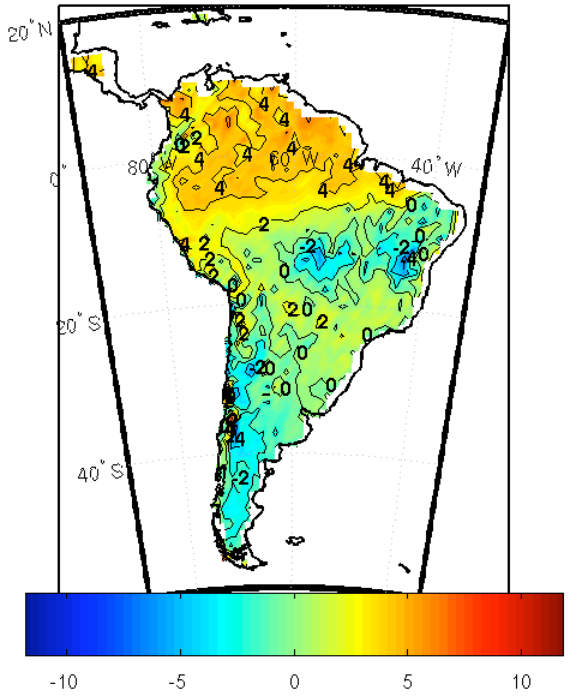


AIRS Level 3 Surface Skin Temperature (v4.0.8 Test)

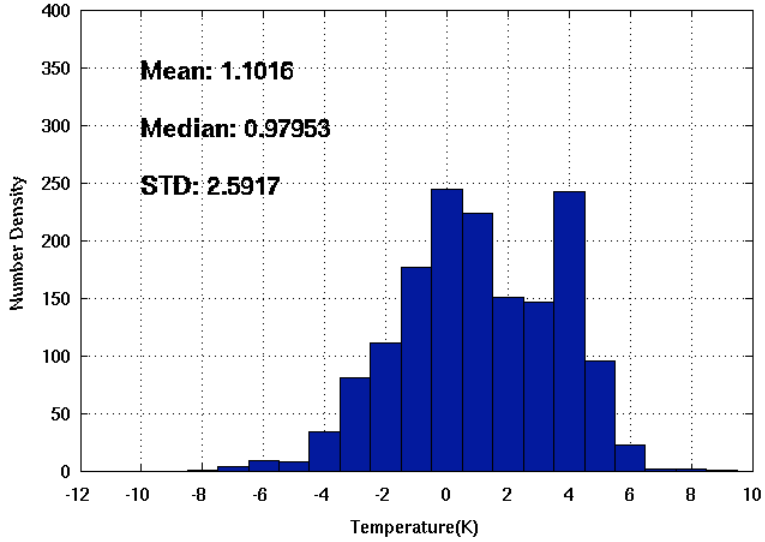


July 2003

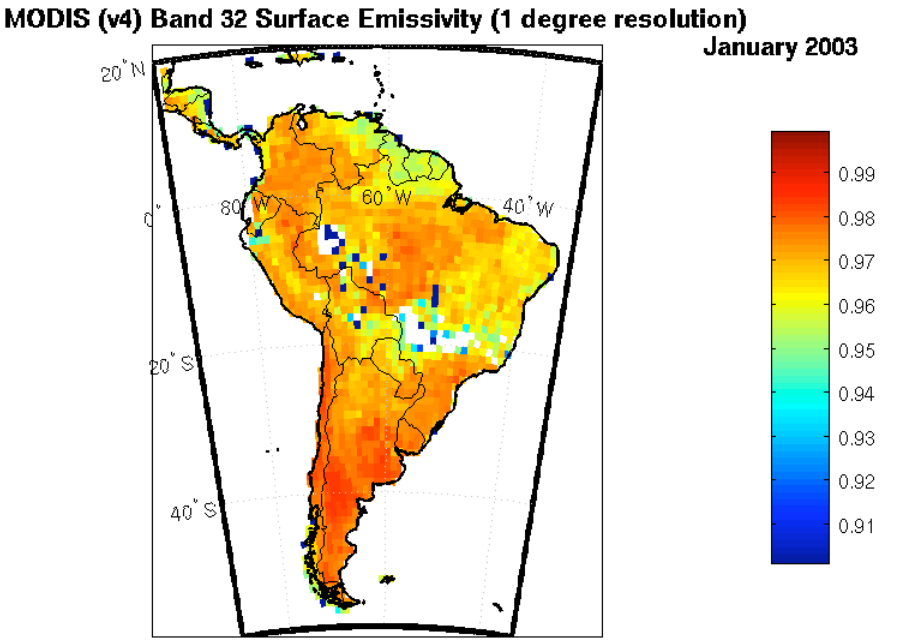
AIRS minus MODIS Surface Skin Temperature

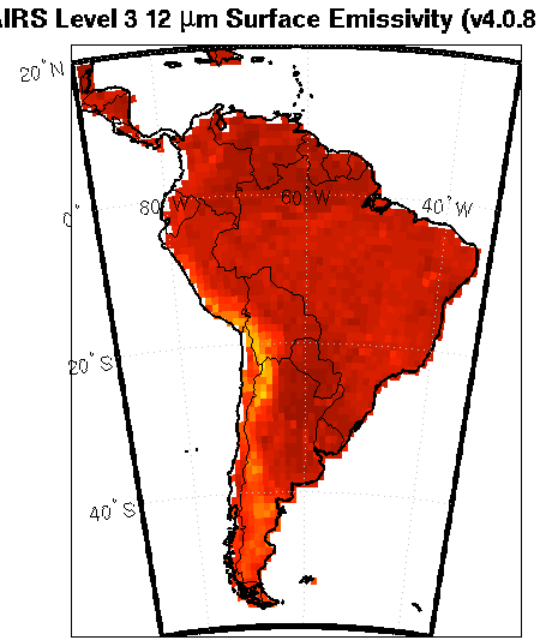


AIRS L3 minus MODIS Land Surface Skin Temperature Distribution

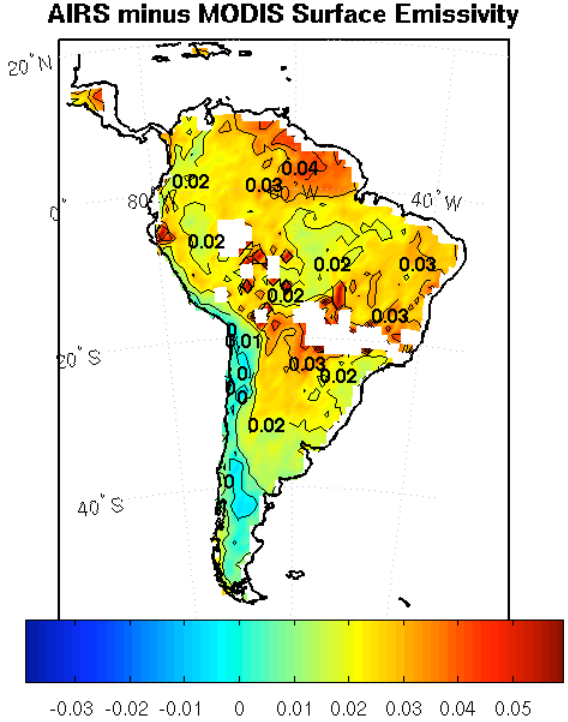


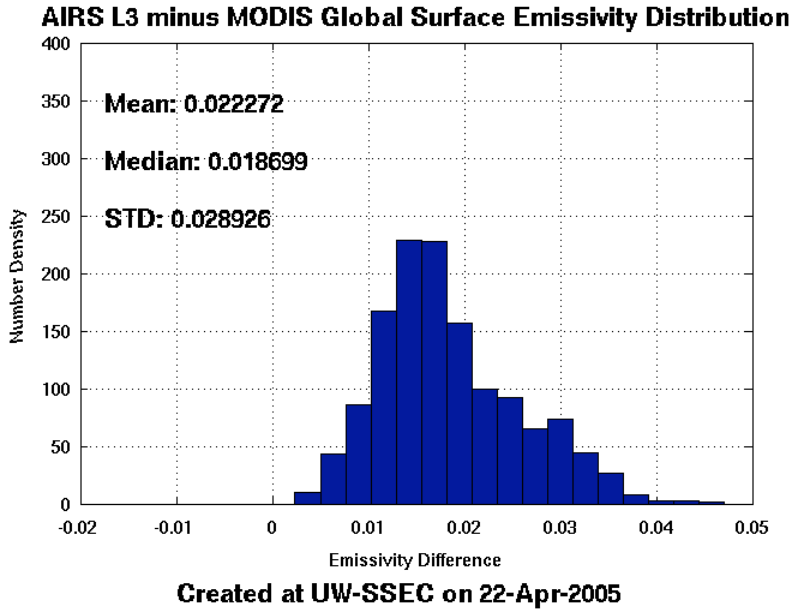
Created at UW-SSEC on 22-Apr-2005

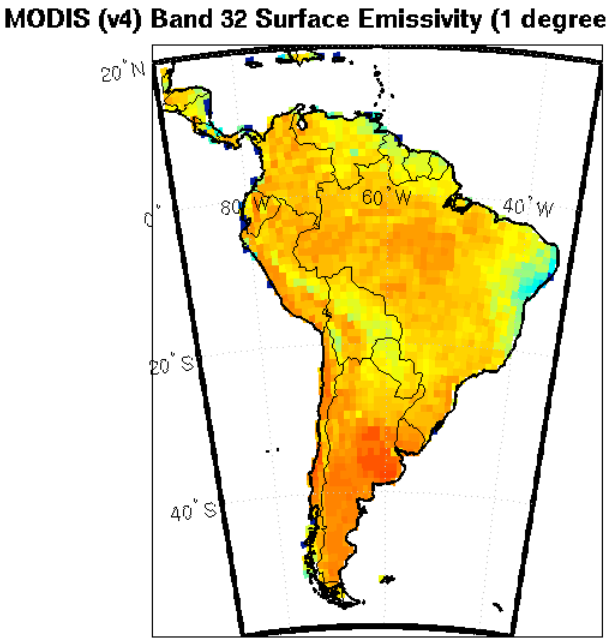


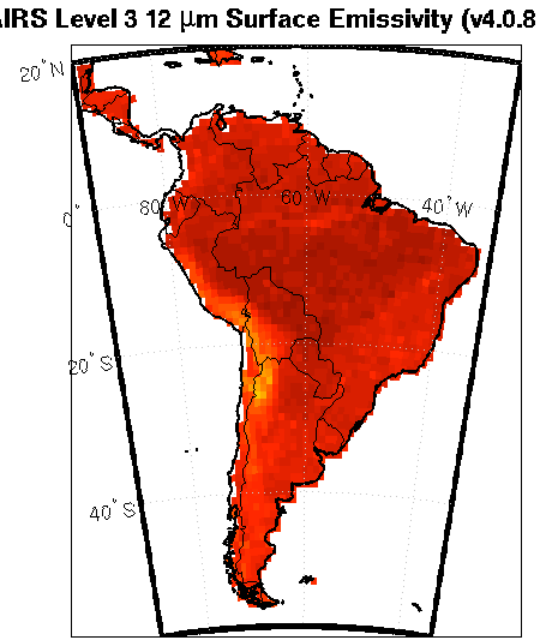


January 2003

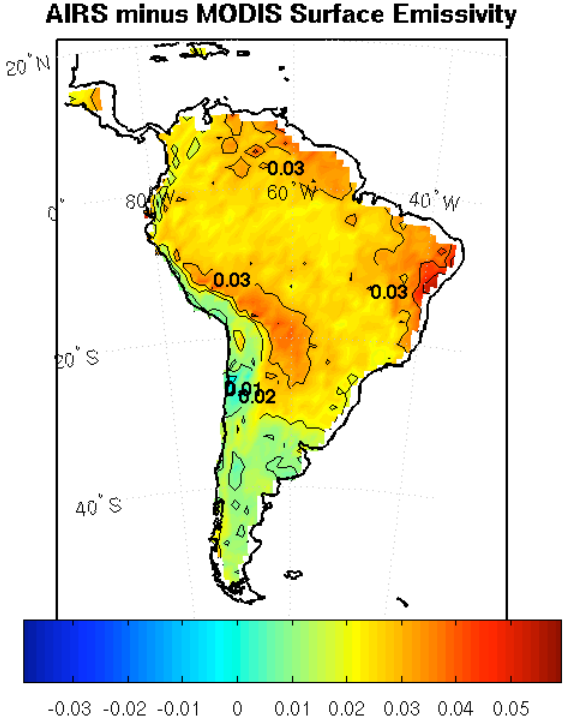


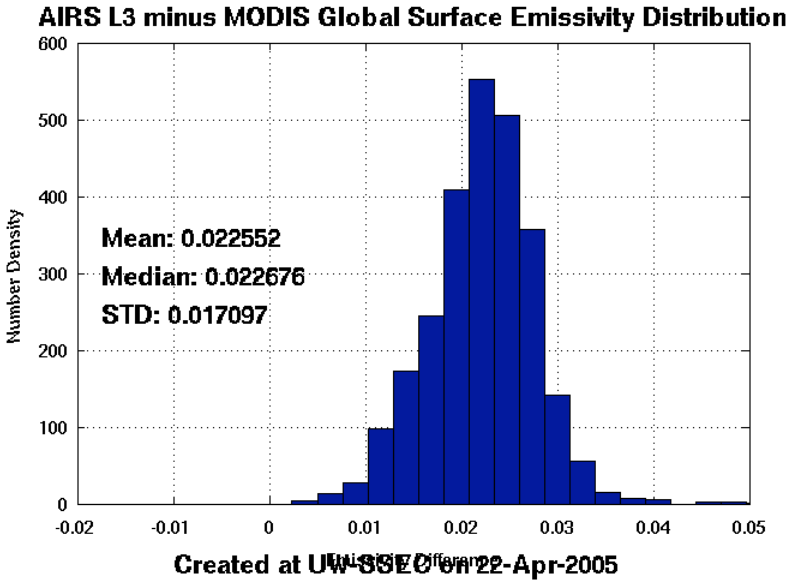


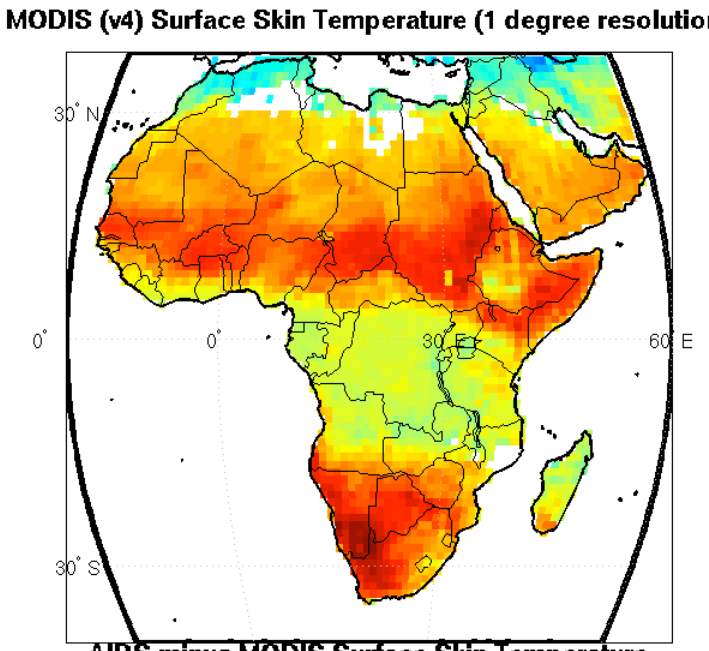

MODIS (v4) Band 32 Surface Emissivity (1 degree resolution)
July 2003
20°N
0°
20°S
40°S
80°W
60°W
40°W
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91

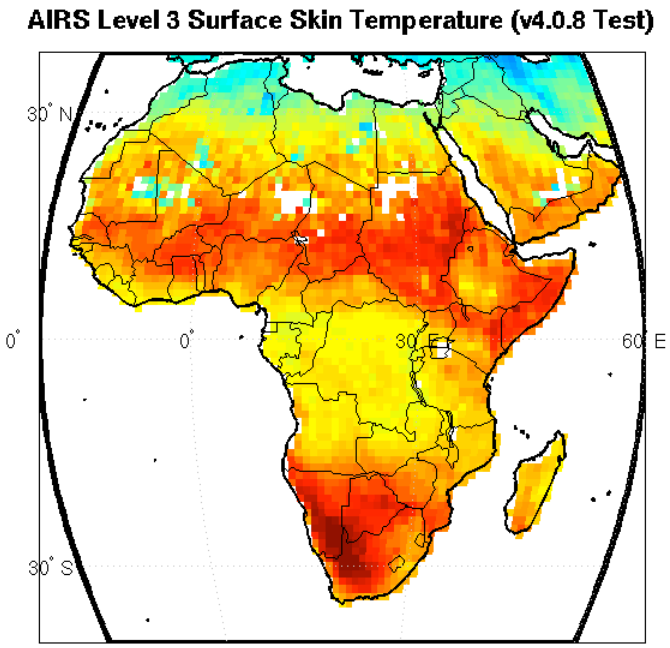

AIRS Level 3 12 μm Surface Emissivity (v4.0.8 Test)
20°N
0°
20°S
40°S
80°W
60°W
40°W

July 2003

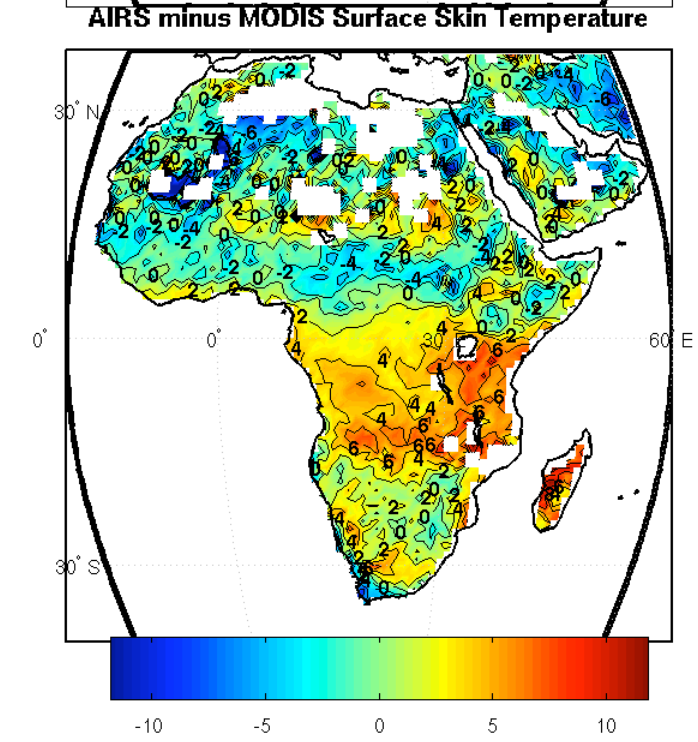

AIRS minus MODIS Surface Emissivity
20°N
0°
20°S
40°S
80°W
60°W
40°W
0.03
0.03
0.03
0.01
0.02
-0.03 -0.02 -0.01 0 0.01 0.02 0.03 0.04 0.05

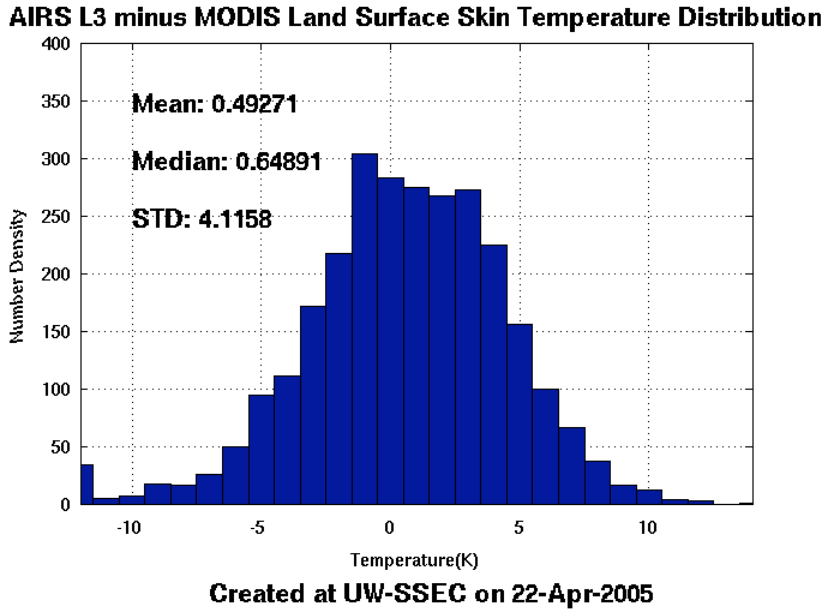

AIRS L3 minus MODIS Global Surface Emissivity Distribution
Number Density
600
500
400
300
200
100
0
Mean: 0.022552
Median: 0.022676
STD: 0.017097
-0.02 -0.01 0 0.01 0.02 0.03 0.04 0.05
Created at UW-SSEC on 22-Apr-2005


MODIS (v4) Surface Skin Temperature (1 degree resolution)
January 2003
30° N
0°
0°
30° E
60° E
30° S
320
310
300
290
280
270

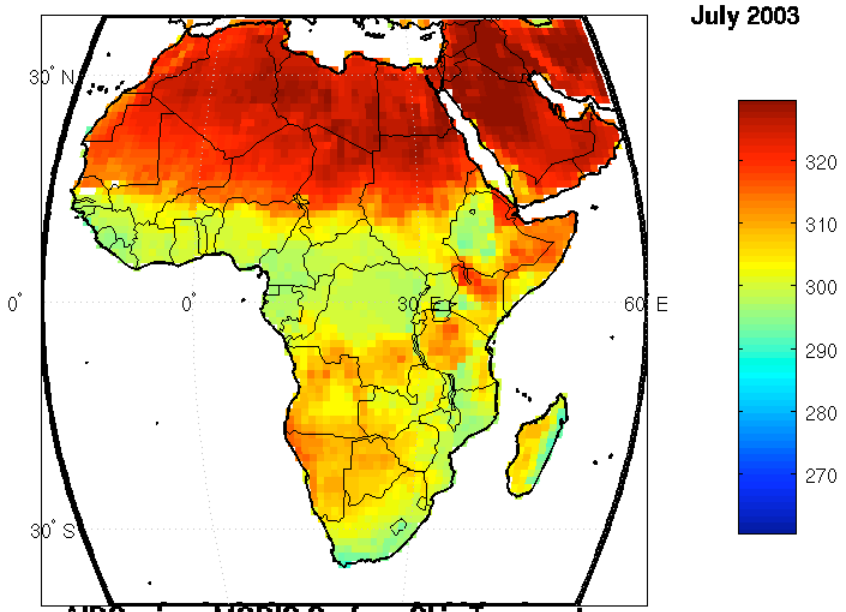

AIRS Level 3 Surface Skin Temperature (v4.0.8 Test)
30° N
0°
0°
30° E
60° E
30° S

Jan. 2003

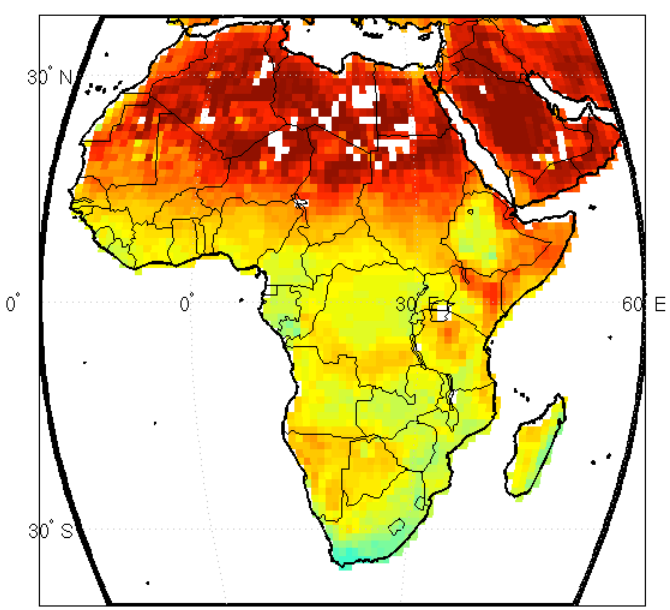

AIRS minus MODIS Surface Skin Temperature
30° N
0°
0°
30° E
60° E
30° S
-10
-5
0
5
10


AIRS L3 minus MODIS Land Surface Skin Temperature Distribution
Mean: 0.49271
Median: 0.64891
STD: 4.1158
Number Density
400
350
300
250
200
150
100
50
0
-10
-5
0
5
10
Temperature(K)
Created at UW-SSEC on 22-Apr-2005

MODIS (v4) Surface Skin Temperature (1 degree resolution)

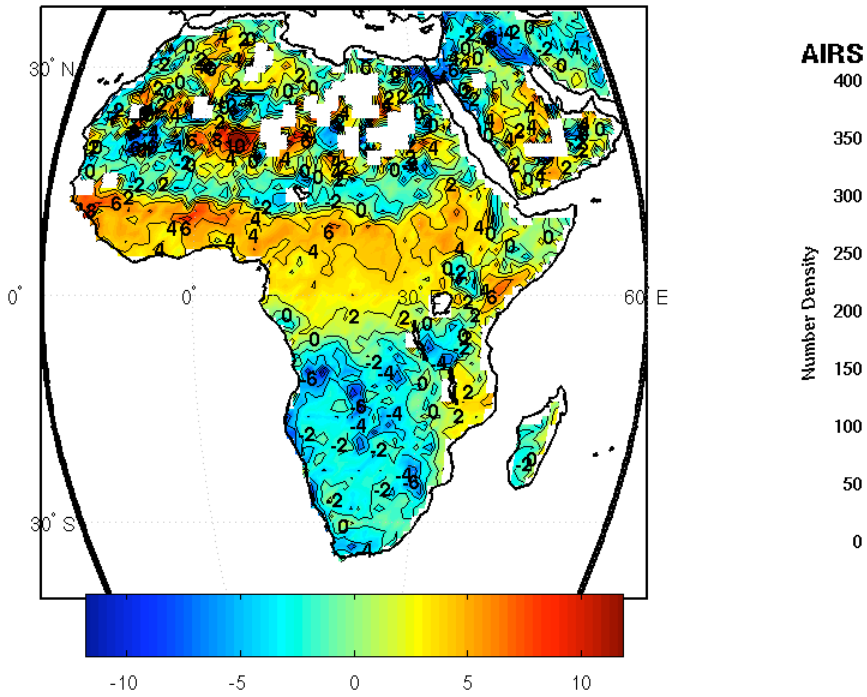


AIRS Level 3 Surface Skin Temperature (v4.0.8 Test)

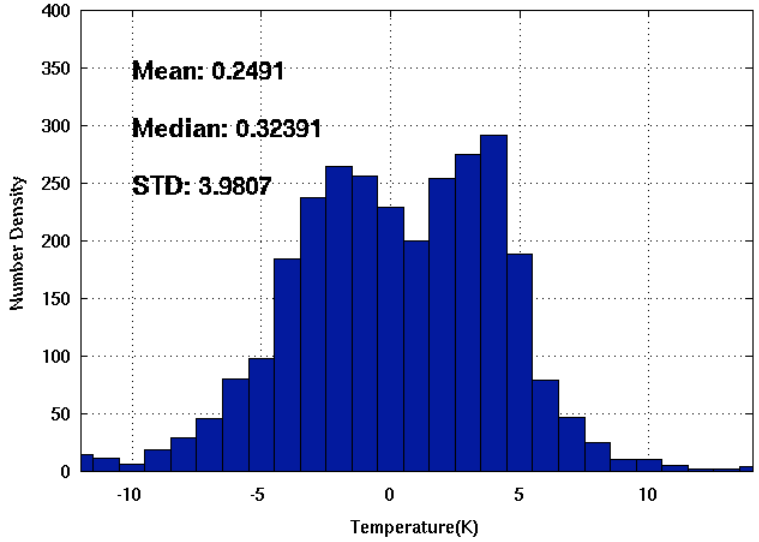


July 2003

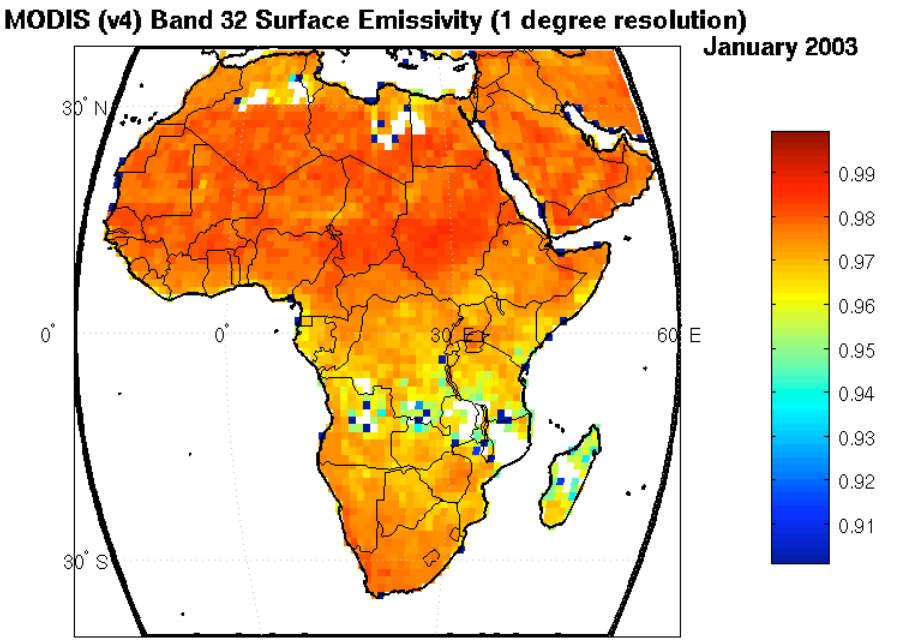
AIRS minus MODIS Surface Skin Temperature

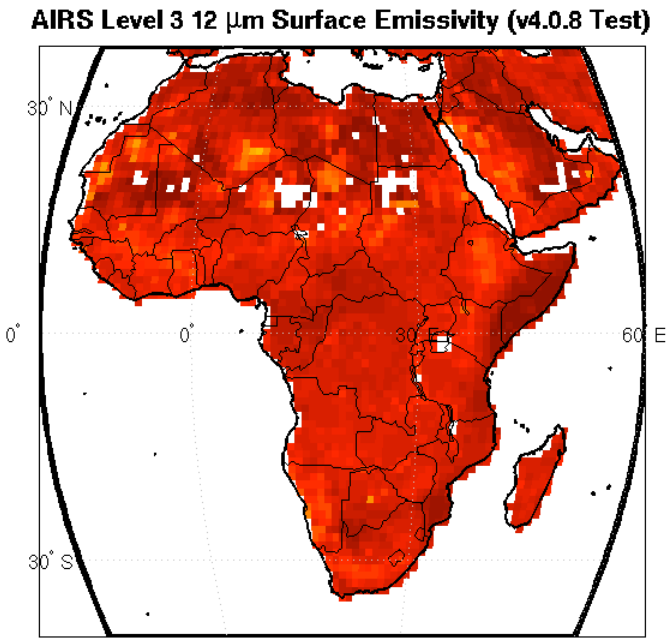


AIRS L3 minus MODIS Land Surface Skin Temperature Distribution

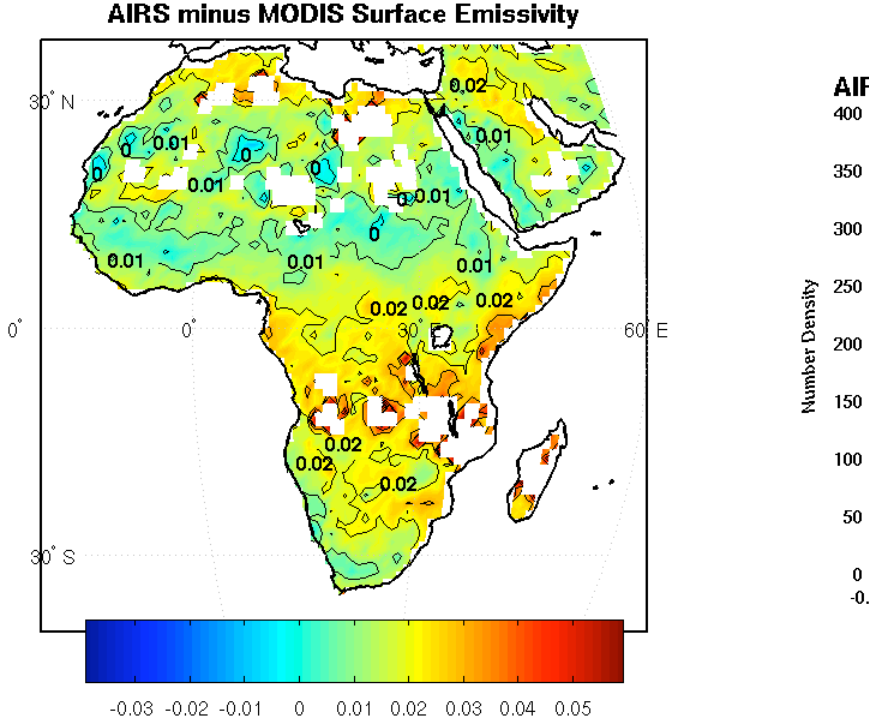


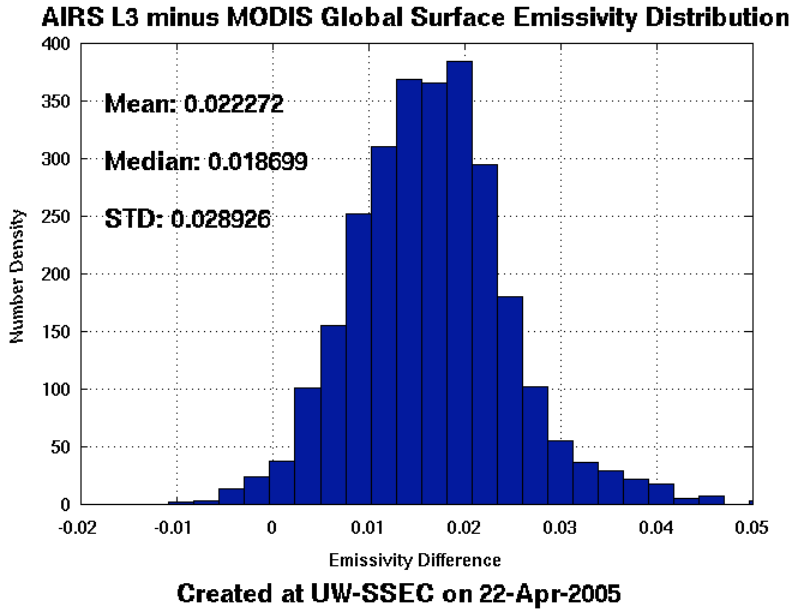
Created at UW-SSEC on 22-Apr-2005

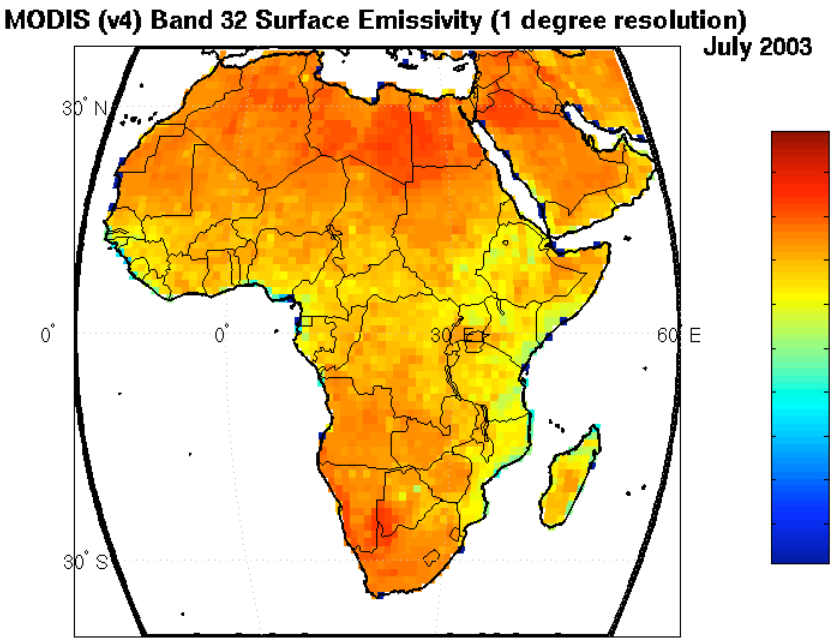

MODIS (v4) Band 32 Surface Emissivity (1 degree resolution)
January 2003
30° N
0°
30° S
0°
30° E
60° E
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91

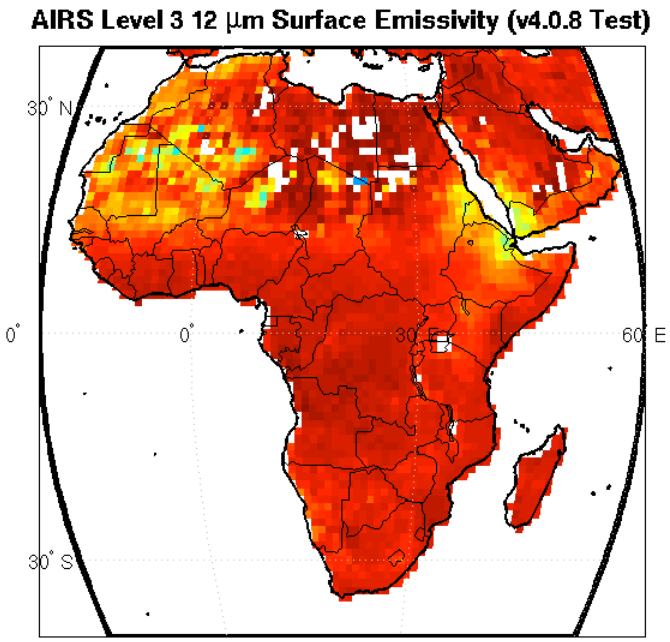

AIRS Level 3 12 μm Surface Emissivity (v4.0.8 Test)
30° N
0°
30° S
0°
30° E
60° E

Jan. 2003

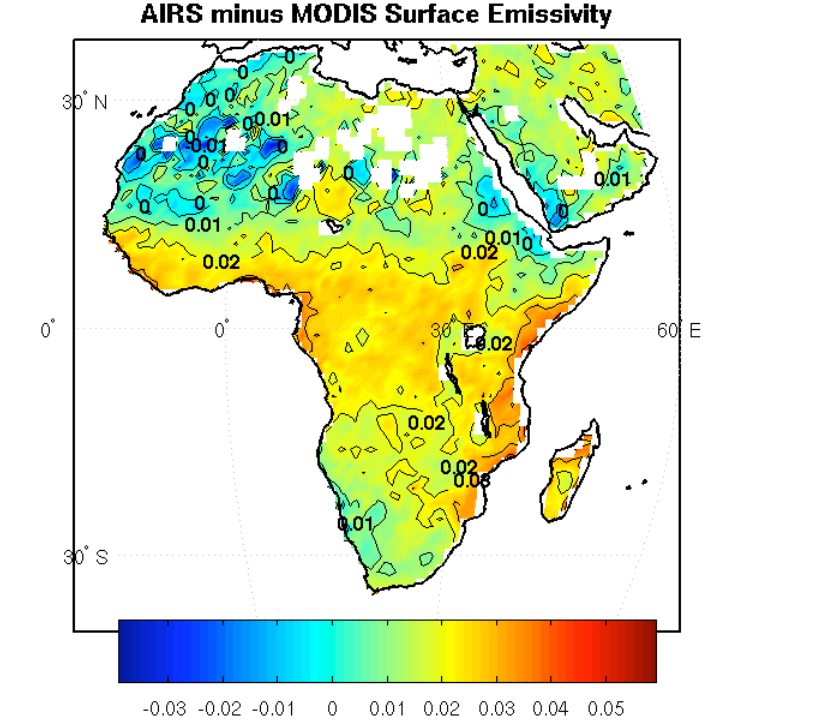

AIRS minus MODIS Surface Emissivity
30° N
0°
30° S
0°
30° E
60° E
-0.03 -0.02 -0.01 0 0.01 0.02 0.03 0.04 0.05

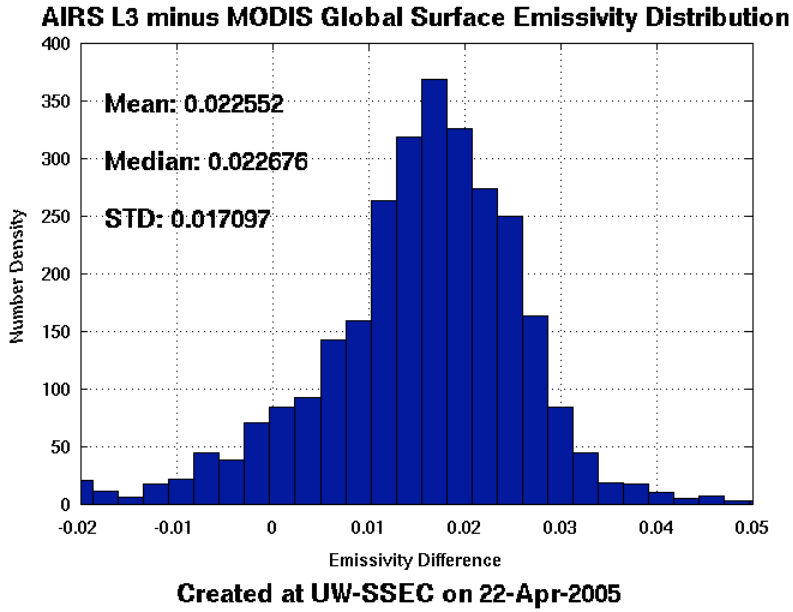

AIRS L3 minus MODIS Global Surface Emissivity Distribution
Mean: 0.022272
Median: 0.018699
STD: 0.028926
Number Density
Emissivity Difference
Created at UW-SSEC on 22-Apr-2005


MODIS (v4) Band 32 Surface Emissivity (1 degree resolution)
July 2003
30° N
0°
30° S
0°
30° E
60° E
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91


AIRS Level 3 12 μm Surface Emissivity (v4.0.8 Test)
30° N
0°
30° S
0°
30° E
60° E

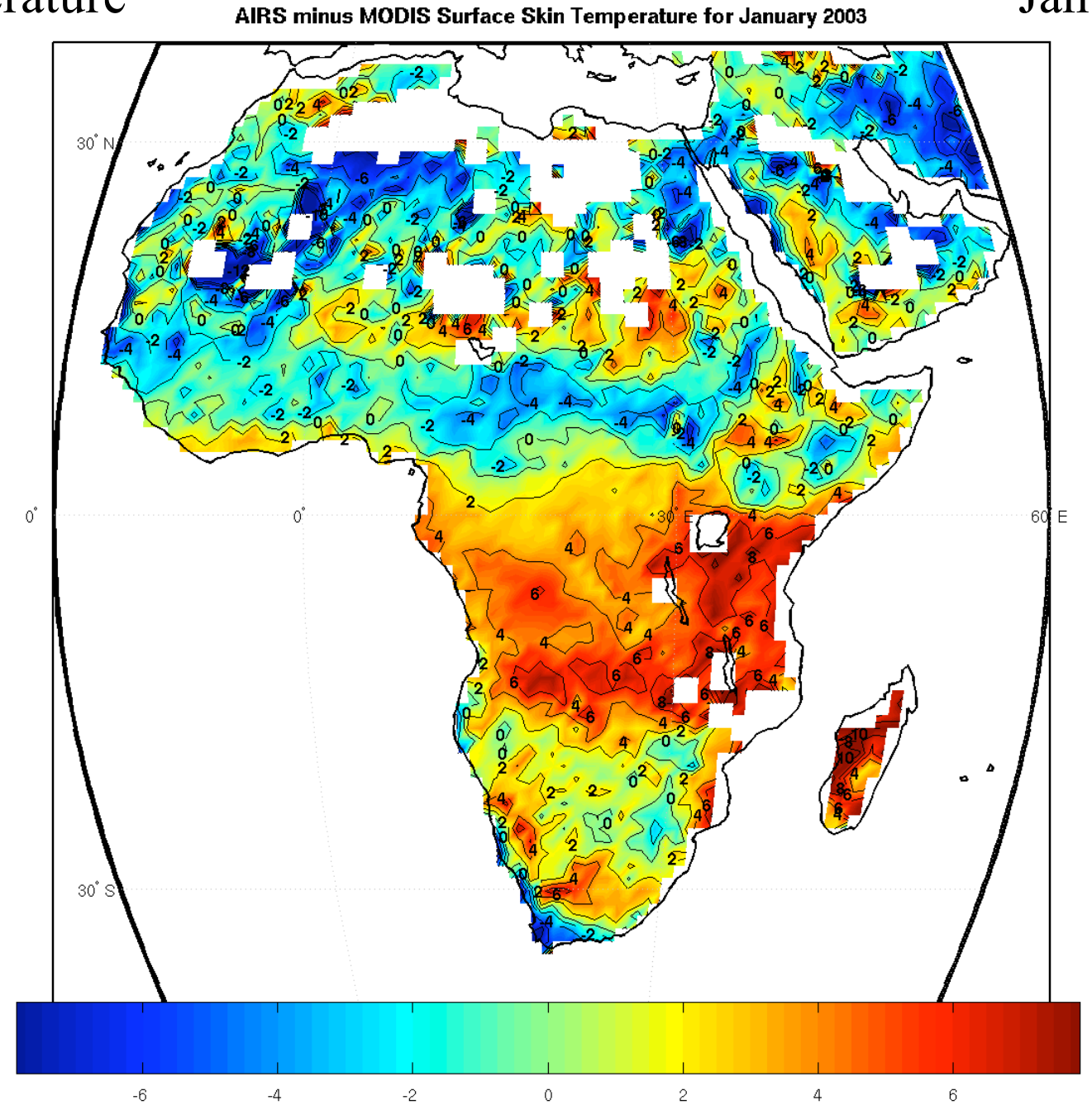
July 2003


AIRS minus MODIS Surface Emissivity
30° N
0°
30° S
0°
30° E
60° E
-0.03 -0.02 -0.01 0 0.01 0.02 0.03 0.04 0.05


AIRS L3 minus MODIS Global Surface Emissivity Distribution
Mean: 0.022552
Median: 0.022676
STD: 0.017097
Number Density
Emissivity Difference
Created at UW-SSEC on 22-Apr-2005

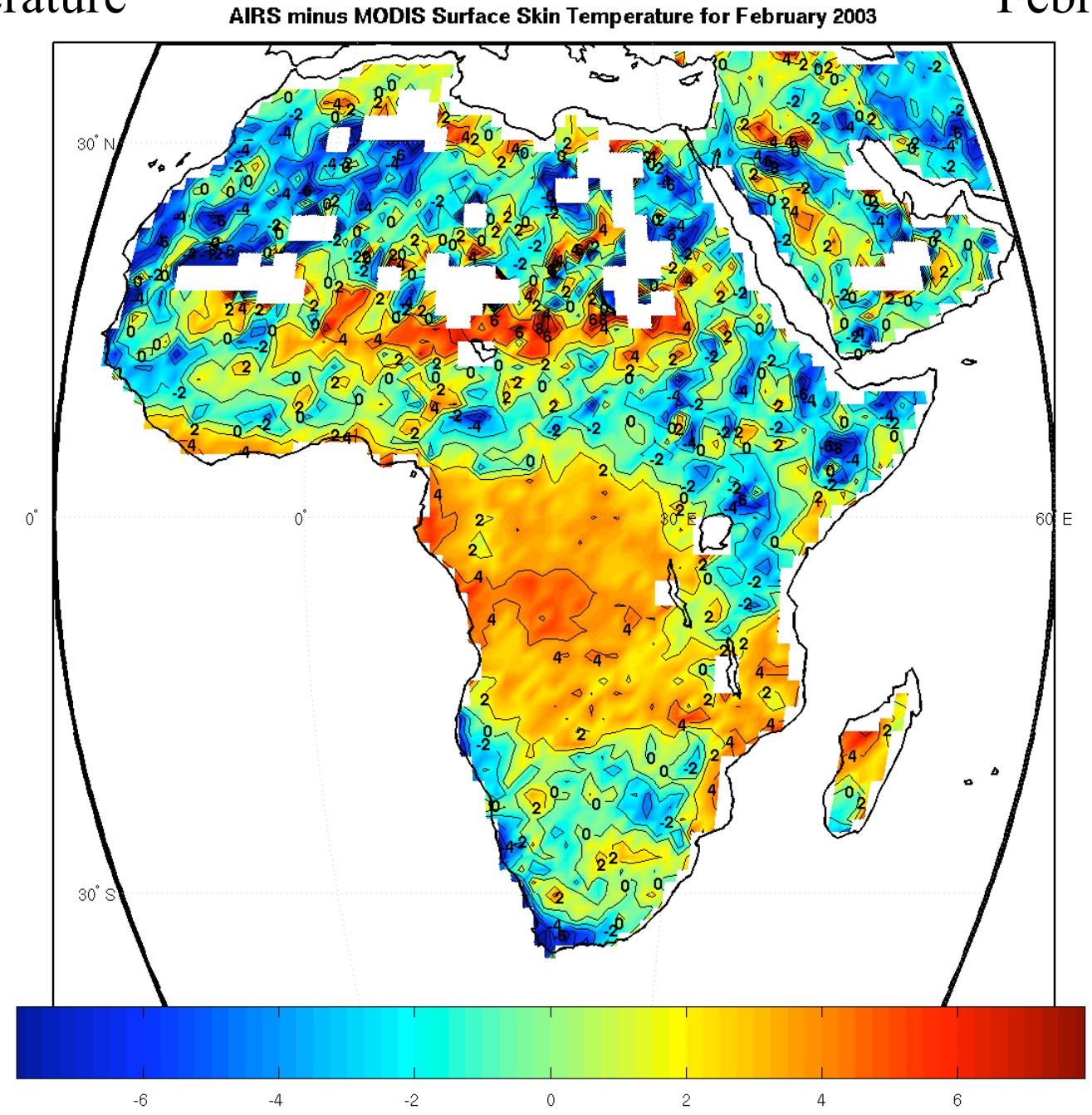
Skin Temperature

January 2003



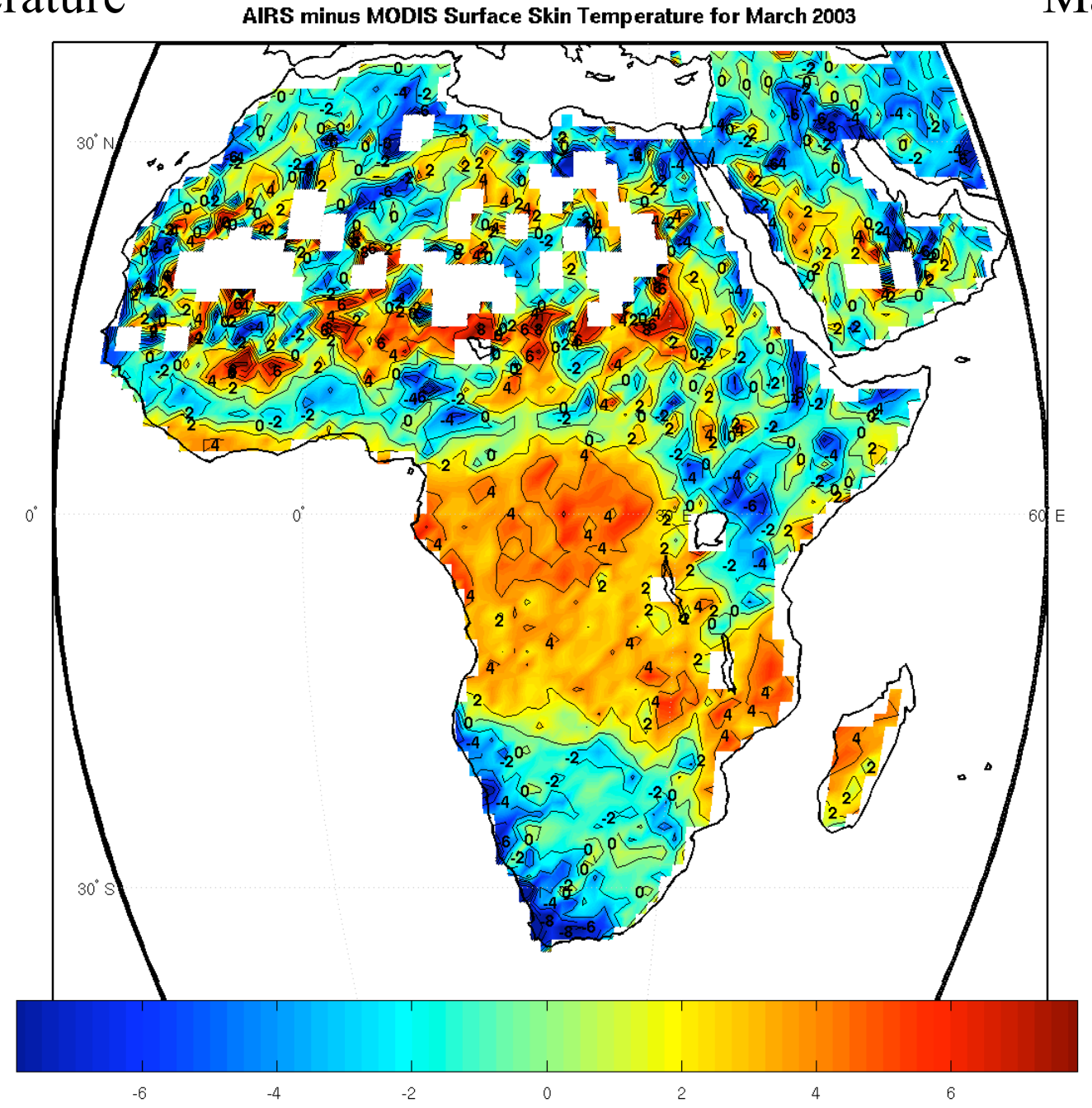
Skin Temperature

February 2003



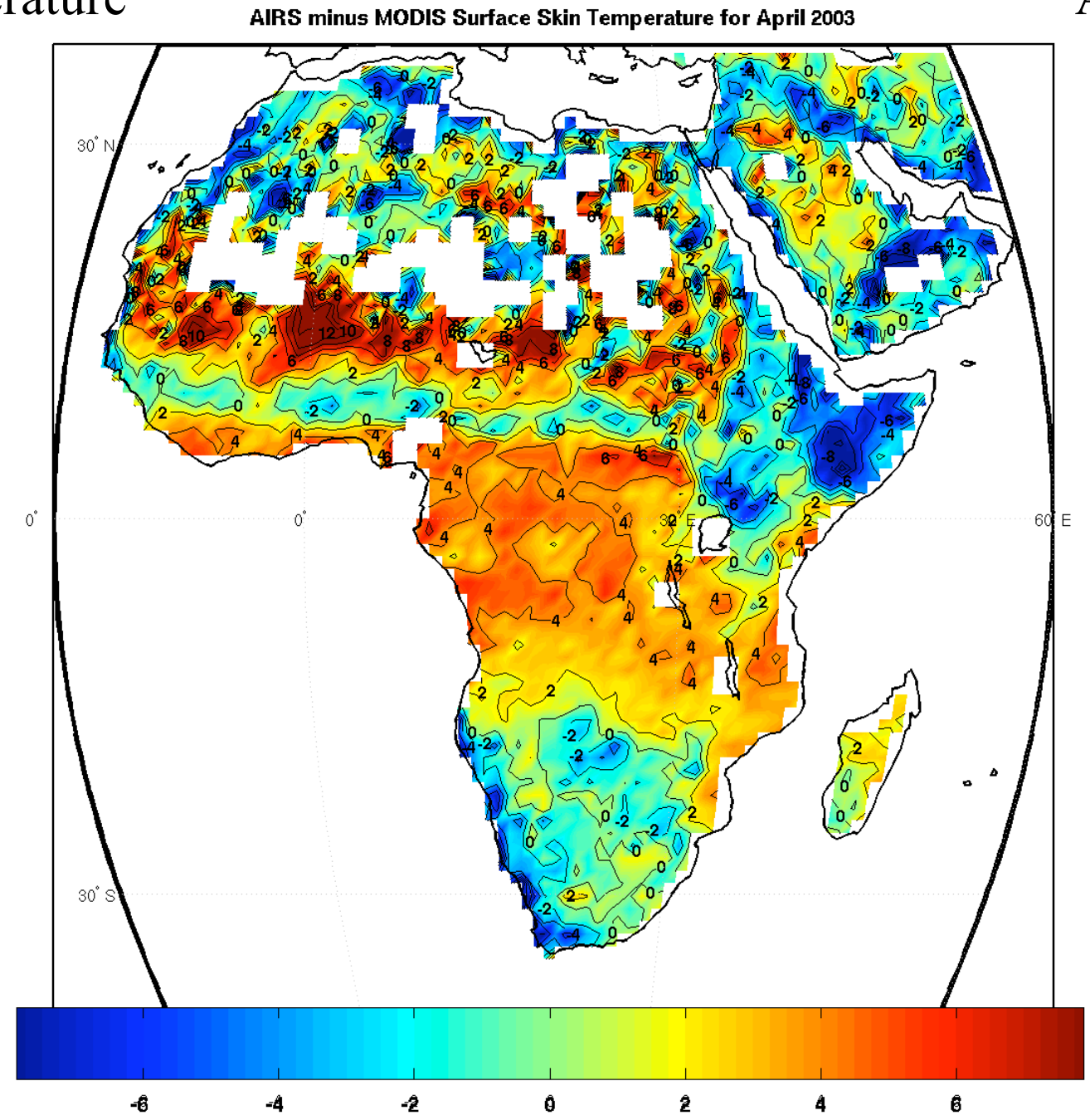
Skin Temperature

March 2003



Skin Temperature

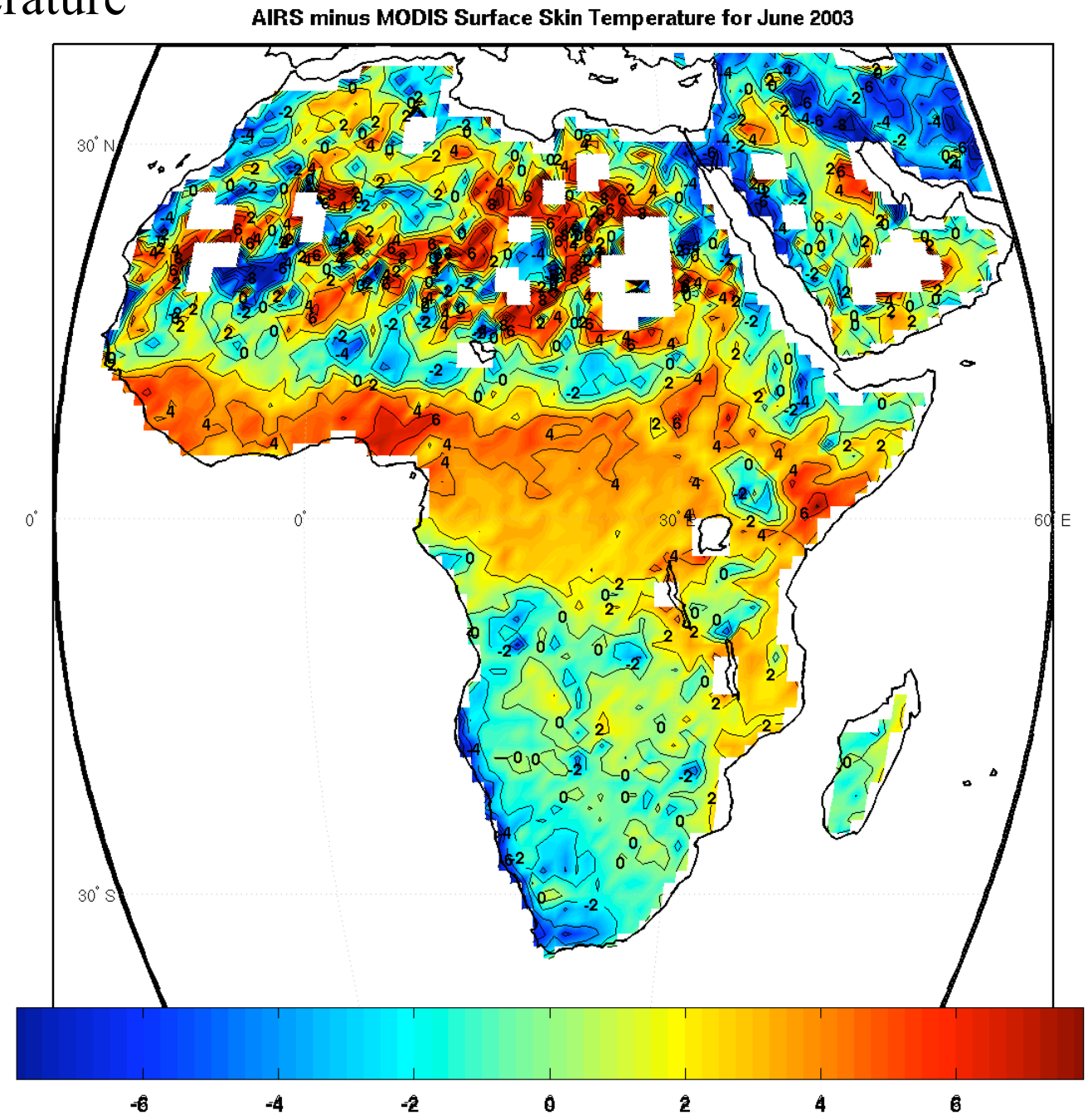
April 2003



AIRS Monthly Composite Missing
for May 2003

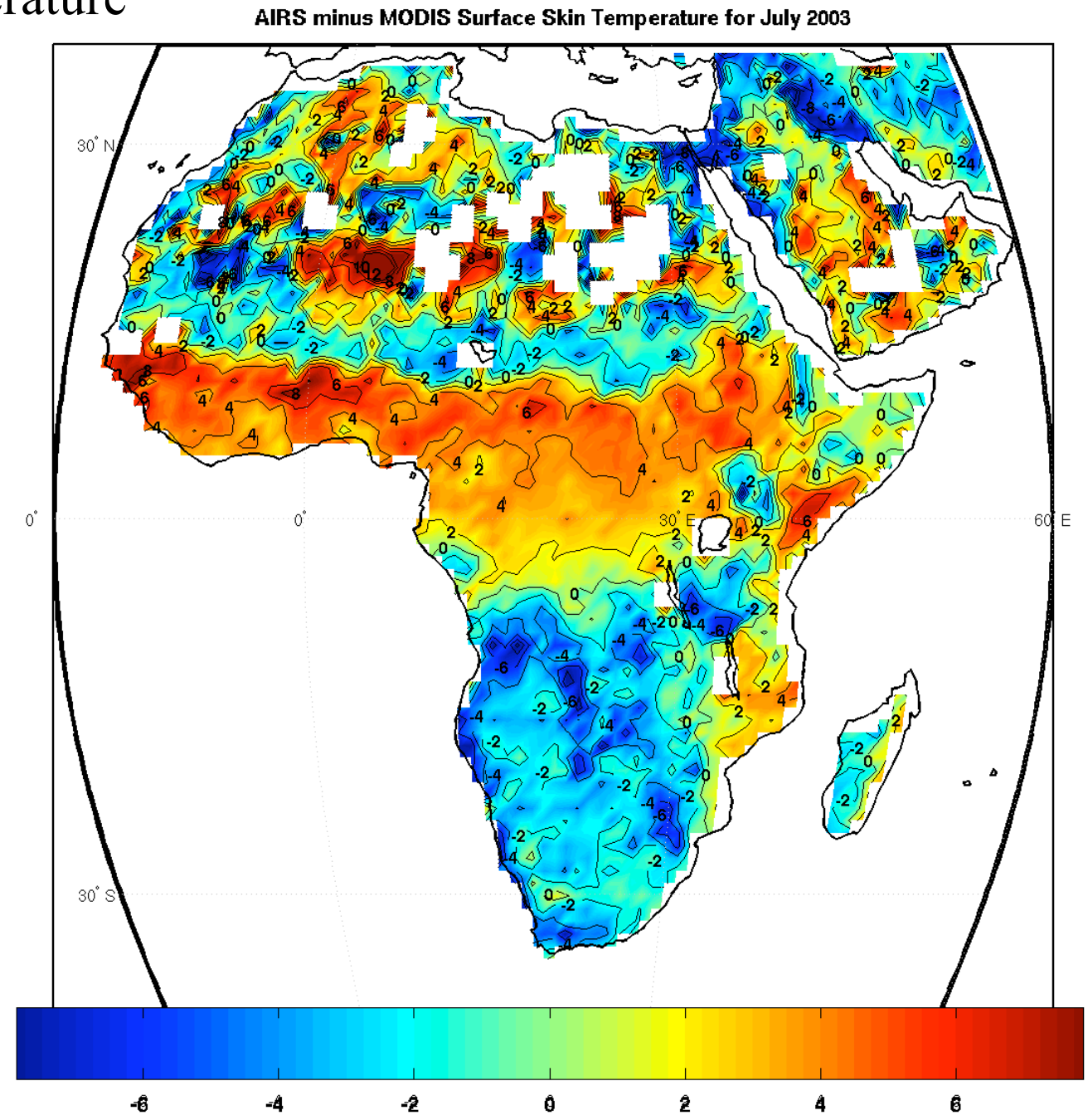
Skin Temperature

June 2003



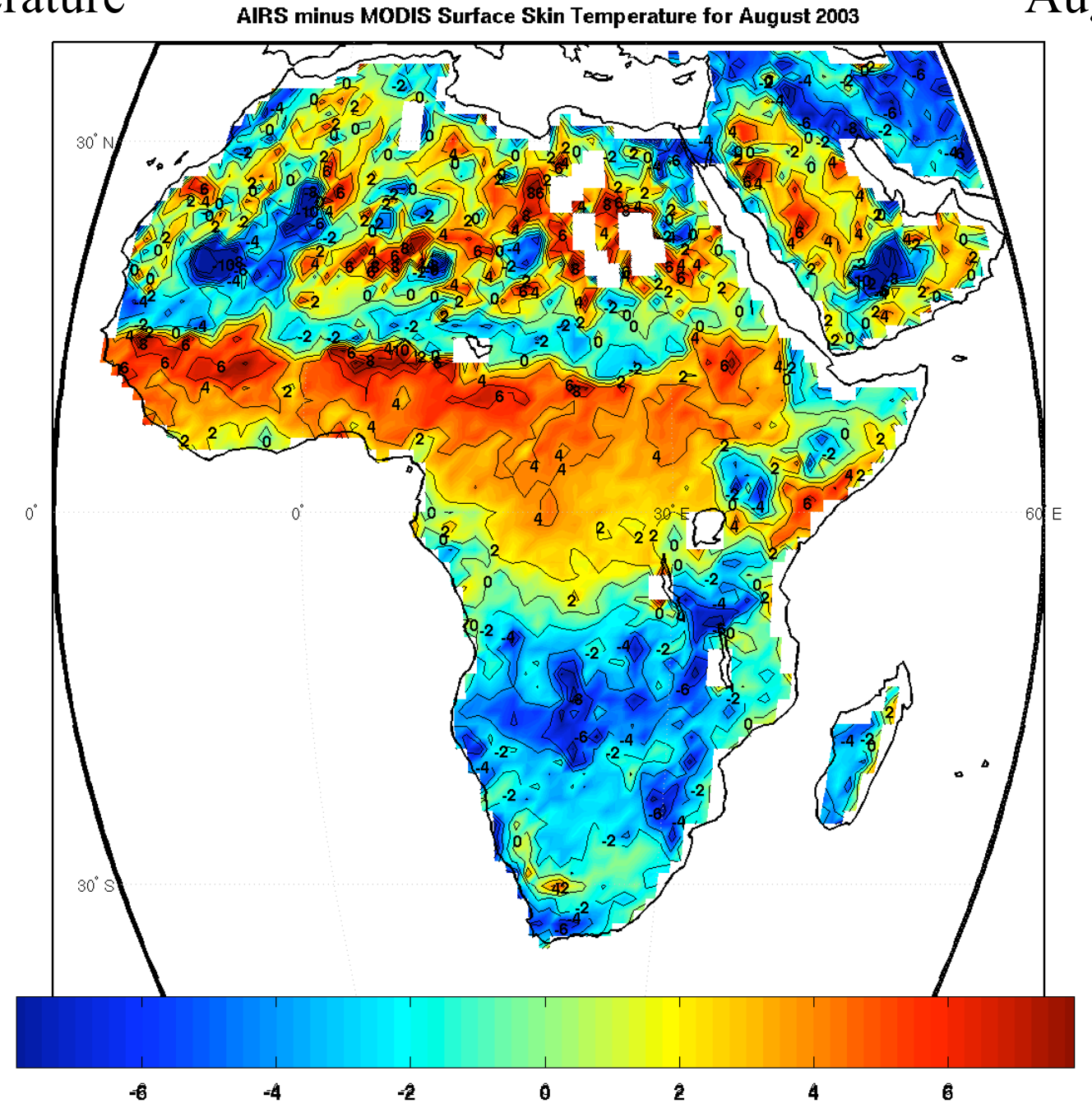
Skin Temperature

July 2003



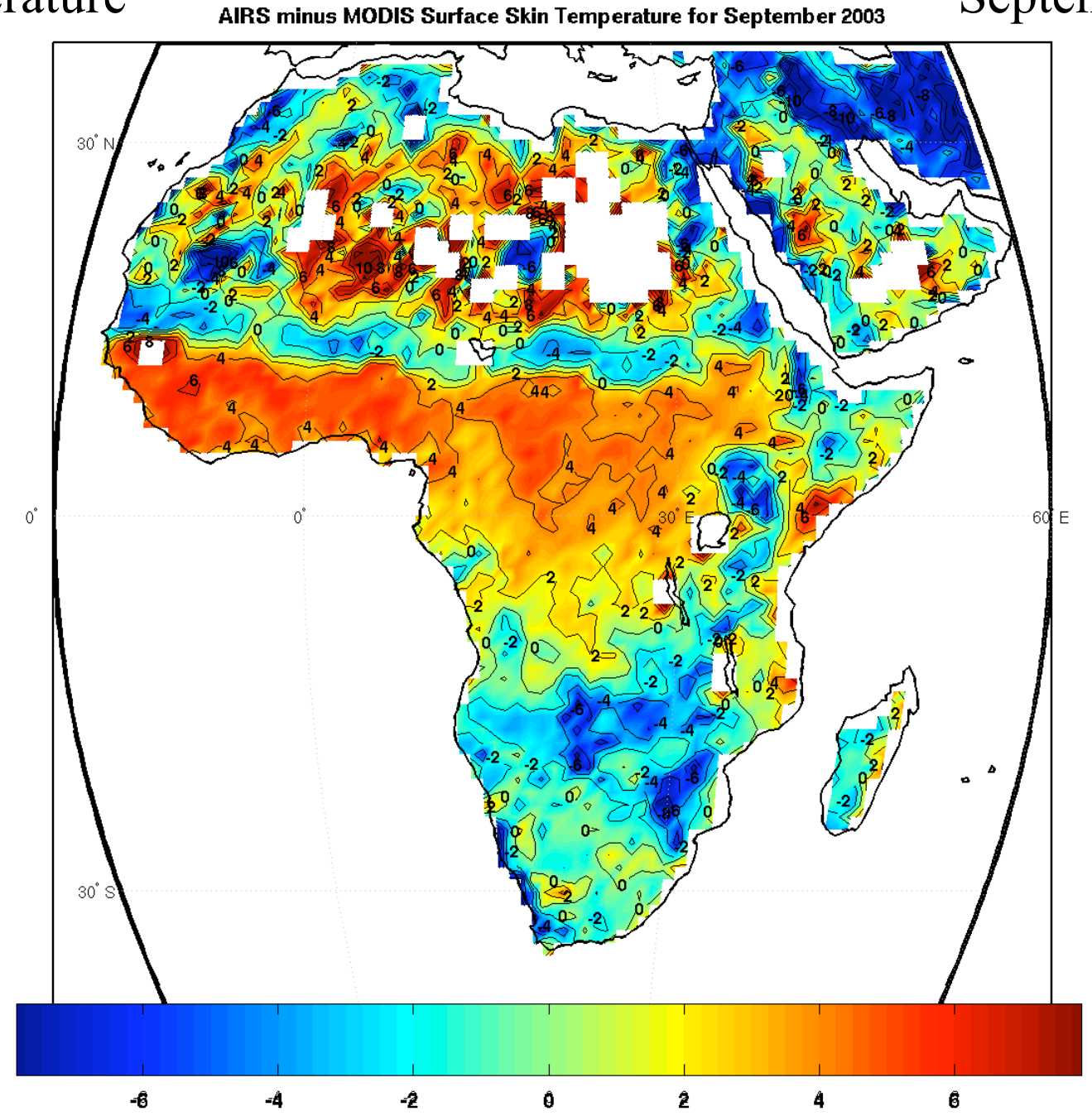
Skin Temperature

August 2003



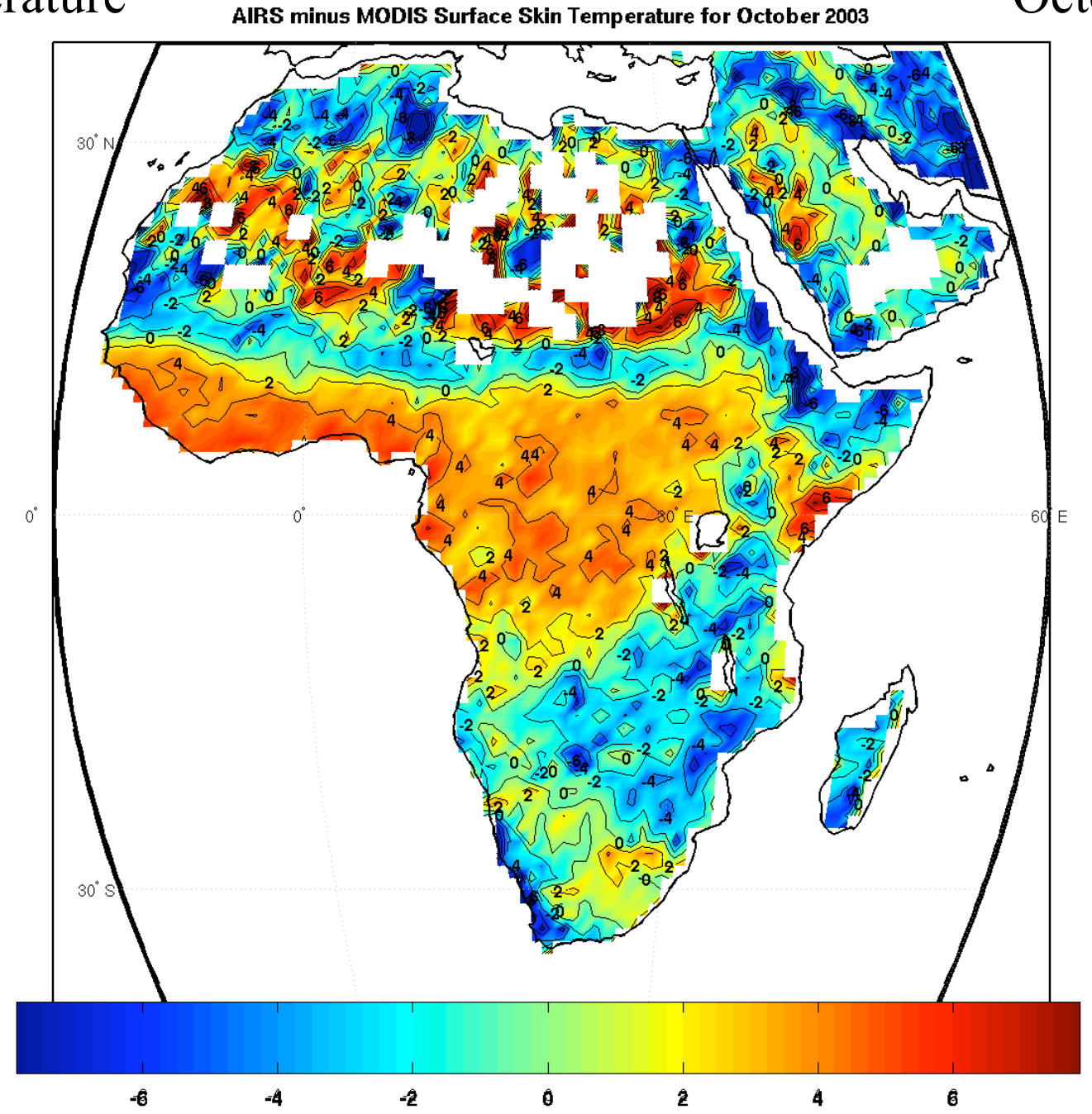
Skin Temperature

September 2003



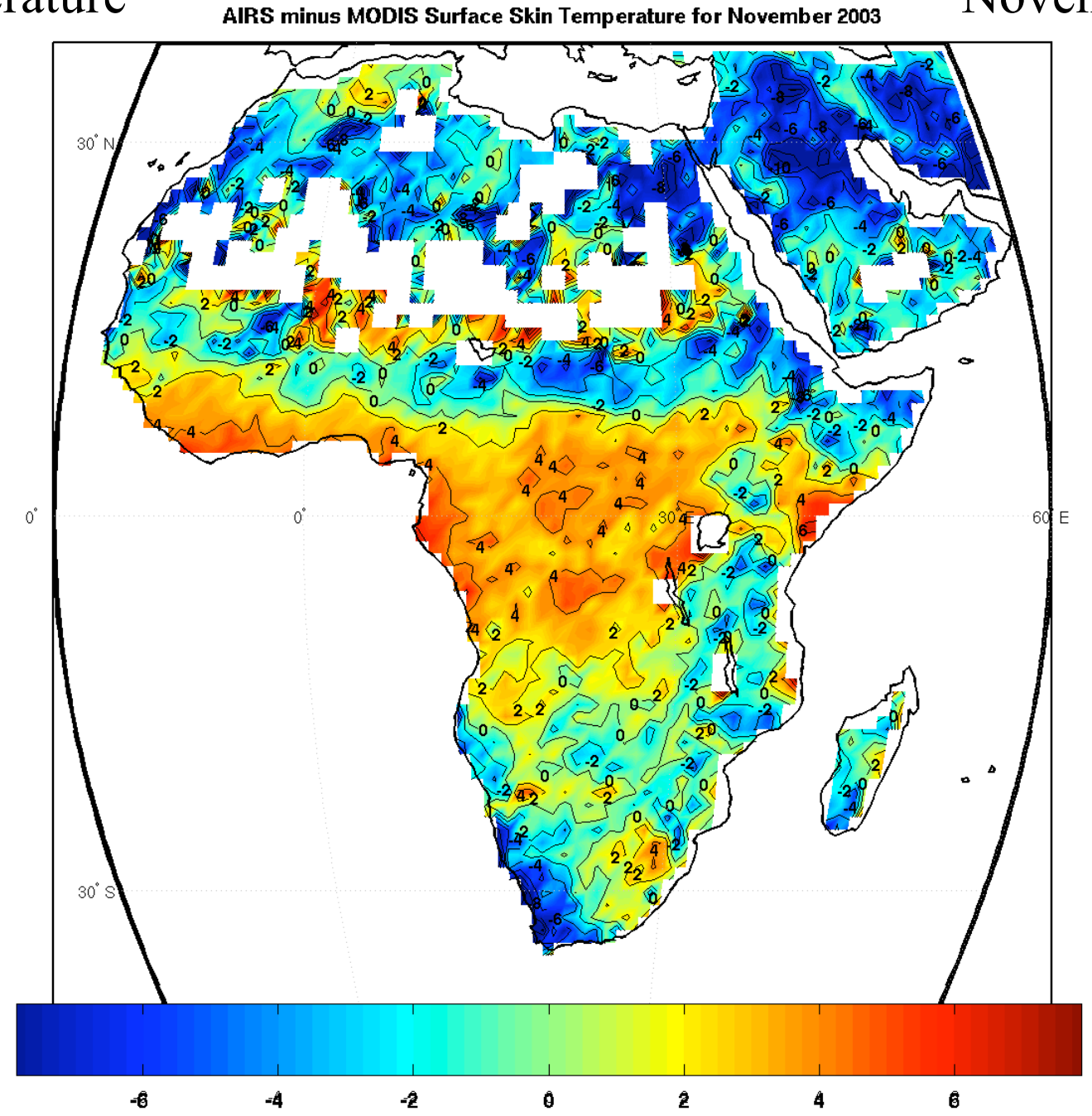
Skin Temperature

October 2003



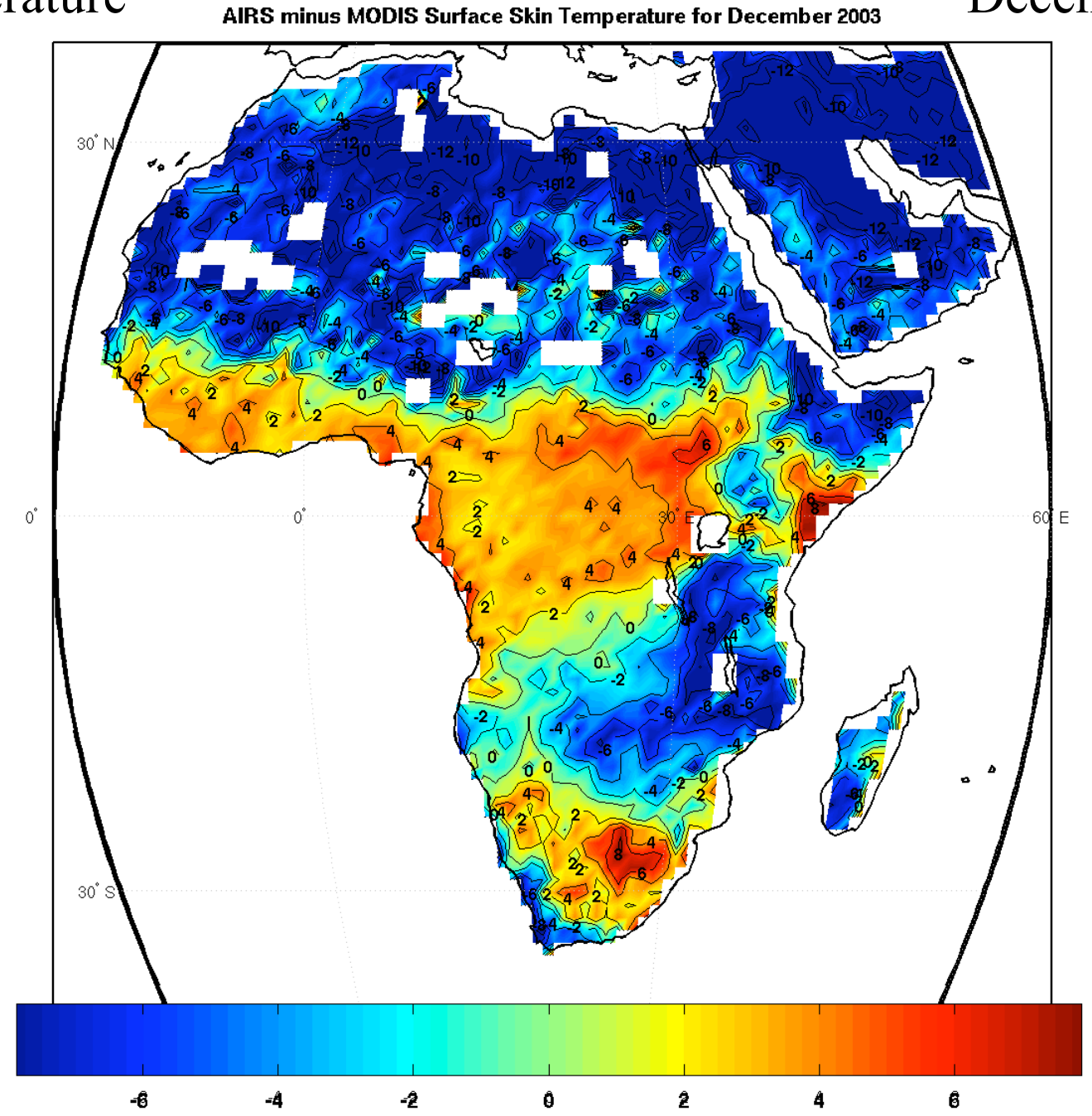
Skin Temperature

November 2003



Skin Temperature

December 2003



AIRS / MODIS Land Product Summary

- The AIRS "test" L3 products using software release version 3.X level 2 products was obtained from JPL.
- The Aqua MODIS MOD11 (collection 4) product was obtained from the Goddard DAAC for this analysis.
- Demonstrated the utility of comparing AIRS L3 products to spatially degraded MODIS L3 products for land surface temperature and IR emissivity validation.
- Complete set of graphics for all geographic regions and all spectral regions is available for the year 2003 at http://gi.ssec.wisc.edu/~airs/knuteson
- A corresponding set of graphics will be added as Goddard begins producing AIRS L3 products based on the data reprocessing using PGE version 4 software.